Towards effective plastic circularity: novel reactive recycling routes for manipulating r-polymers microstructure

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Despite the huge advantages of the plastic recycling industry in the last years, there are still many technological hurdles severely limiting the achievement of an effective plastic circularity. This last mostly due to progressive deterioration of the polymer microstructure during reprocessing, resulting in a gradual loss of processability and properties, ultimately compromising the possibility of using r-polymers for applications with high engineering requirements. In fact, especially for polyolefins, usually the mechanical recycling is considered a downcycling process. In this work, different routes of reactive recycling for polyethylene terephthalate (PET) and polyolefins (namely, polypropylene (PP) and high-density polyethylene (HDPE)) were proposed. In particular, different types of commercially available additives provided by Nexam Chemical were introduced within the selected r-polymers (for which the thermomechanical degradation usually experienced during a mechanical recycling process was simulated through subsequent reprocessing steps in a twin-screw extruder), aiming at verifying the possibility of manipulating their microstructure (through the rebuilding of the molecular weight or the targeting of the macromolecular architecture) for achieving high value-added recycled materials, potentially employable in applications with high engineering requirements.

Actually, for rPET the utilization of chain extenders for rebuilding the polymer molecular weight has been already documented in the literature. However, in this research this strategy was applied for PET/HDPE blends, trying to reproduce the typical conditions of a real mechanical recycling scenario, in which the polymer of interest unavoidably contains certain amounts of contaminants deriving from a non-fully effective sorting step. The results of the rheological characterization highlighted a beneficial effect of the additive in promoting the achievement of higher viscosity values (hence, molecular weight) as compared to the pristine reprocessed materials. Owing to the microstructural modifications induced by the additive, cast-extruded films based on rPET and r(PET/HDPE) were successfully obtained, demonstrating the effectiveness of the proposed route in enhancing the processability of PET-based recyclates.

Differently from PET, for polyolefins there is currently no solution available to restore the molecular weight, apart from traditional cross-linking strategies that, however, are not selective and do not rebuild the molecular weight through an end-to-end reattachment mechanism. In a second part of this research, two different additives (namely, NEXAMITE® R201 and NEXAMITE® R305) were introduced in PP and HDPE, respectively. In the case of PP, the obtained results clearly demonstrated that the introduction of NEXAMITE® R201 can effectively prevent the decrease of the molecular weight of PP, especially when the additive is added in a low degraded PP (i.e. in the case of pre-consumer recycling). Furthermore, it was shown that the additive can induce some melt structuring phenomena, involving the obtainment of branched structures or crosslink points, especially if the melt processing is carried out for long residence times.
As far as rHDPE is concerned, it was demonstrated that the additive is capable of selectively direct the

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thermo-mechanical degradation pathway of HDPE towards the achievement of long-chain branching microstructure, which in turn promotes the obtainment of high melt strength values, beneficial for the further processing of the rHDPE through technologies dominated by the elongational flow.

Keywords: Mechanical recycling, Upcycling, Waste valorisation, plastic circularity, rheology