MECHANICAL RECYCLING OF POLYPROPYLENE: EFFECT OF A REPAIR ADDITIVE ON FLOW CHARACTERISTICS AND PROCESSABILITY

R. Arrigo, G. Bernagozzi and A. Frache

Department of Applied Science and Technology, Polytechnic of Turin, Viale Teresa Michel 5, Alessandria, Italy

rossella.arrigo@polito.it, giulia.bernagozzi@polito.it, alberto.frache@polito.it

INTRODUCTION

Plastic recycling is a key aspect to achieve effective polymer circularity, especially for polyolefins for which usually the mechanical recycling is considered a downcycling process. The last, due to the progressive deterioration of the polymer microstructure during the reprocessing that involves a gradual loss of processability and properties and compromises the added value of r-polyolefins. In this work, the effects of the thermomechanical degradation on the microstructure of polypropylene (PP) were assessed by subjecting the polymer to multiple extrusion cycles, aiming at investigating the evolution of the molecular weight and of the macromolecular architecture of PP typically occurring in a mechanical recycling process. Furthermore, a commercially available additive capable of restoring the PP molecular weight was introduced and its effects were evaluated following two different strategies that simulate pre-consumer or post-consumer mechanical recycling. The additive-induced microstructural modifications of PP during the reprocessing cycles were monitored through rheological, thermal, and spectroscopic analyses. The obtained results allowed correlating the achieved microstructural evolutions to the processability of the recycled PP, demonstrated the possibility of achieving r-PP with different macromolecular architectures and, hence, flow characteristics, endowed with tunable and adaptable processability.

EXPERIMENTAL

Materials

A homopolymer PP (Moplen HP500N supplied by Lyondellbasell) was used. The commercially available additive NEXAMITE® R201 (hereinafter named NEX) was provided by Nexam Chemical. The additive was introduced in PP at 5 wt.%.

Preparation

The mechanical recycling of PP, with and without NEX, was simulated by subjecting the material up to 9 reprocessing cycles performed using a Process 11 (Thermo Fisher Scientific) twin screw extruder. NEX was introduced during the first reprocessing cycle of PP (rPP+NEX@n1) or in PP already subjected to 8 reprocessing cycles (rPP+NEX@n9).

Characterizations

The rheological behavior of the investigated materials was assessed using a strain-controlled rheometer ARES from TA Instruments.

RESULTS AND DISCUSSION

The rheological characterization of PP with and without NEX subjected up to 9 reprocessing cycles showed that the introduction of the additive is beneficial in mitigating the loss of PP molecular weight and in maintaining unmodified the polymer processability. In fact, as observable from Fig. 1 reporting the variation of the zero-shear viscosity η_0 (hence, of the molecular weight) as a function of the reprocessing cycle, pristine PP shows a dramatic drop of η_0 passing from the virgin material to the one reprocessed 9 times. Otherwise, for the sample rPP+NEX@n1 the decreasing rate of the viscosity is remarkably lower, indicating that the introduction of the additive was beneficial in mitigating the loss of PP molecular weight.

Furthermore, the analysis of the complex viscosity curves highlighted a progressive amplification of the Newtonian behavior as a function of the re-processing cycles for pristine PP, while for the sample containing NEX the trend of the complex viscosity as a function of the frequency is almost unmodified as a function of the reprocessing cycles. Besides, the results reported in Fig.1 indicate a significant recover of the polymer molecular weight also when NEX is introduced in a heavily degraded PP (rPP+NEX@n9), hence suggesting its possible application for the recovery of the molecular weight of post-consumer recycled PP.

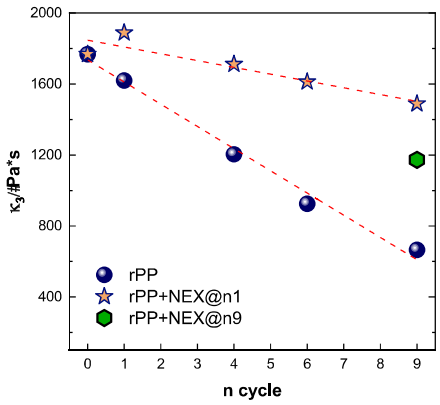

Fig. 1 Zero-shear viscosity (η_0) as a function of the number of reprocessing cycles for virgin and multi-extruded rPP, rPP+NEX@n1 and rPP+NEX@n9

Furthermore, it was also showed that NEX can induce some melt structuring phenomena (as observable for the relaxation spectra depicted in Fig.2), involving the obtainment of branched structures or crosslink points, especially if the melt processing is carried out for long residence times.

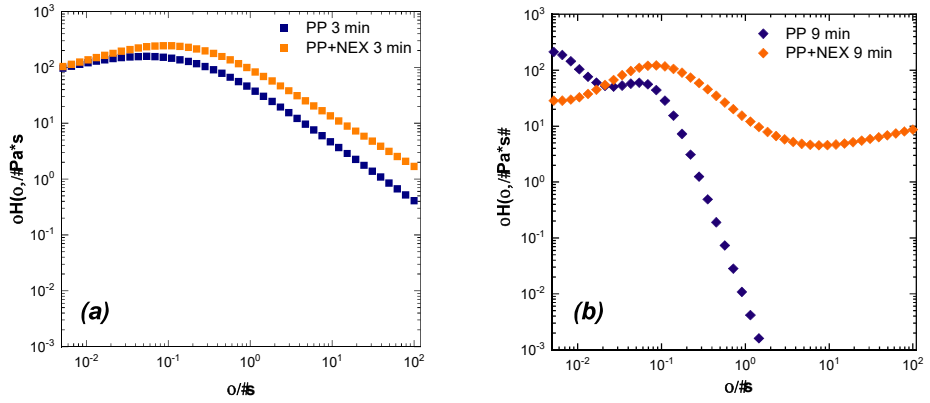

Fig. 2 Weighted relaxation spectra of PP processed for (a) 3 minutes and (b) 9 minutes with and without NEX

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