Recycling Process by Dissolution/polymerization: Giving New Life to Waste Expanded Polystyrene

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Abstract

Plastic recycling has been enjoying a considerable boom since 2016. This has been driven, on one hand, by players which complain of an inadequate collection and recycling of plastic waste with a view to an economy of closed loop recycling for polymers, from another hand by the alarming images of plastic waste in the waters of rivers, seas, oceans, destroying ecosystems. The topicality of the problem is intensifying the challenges that the recycling industry has faced, such as completeness of collection, problem-oriented sorting and the availability of large quantities of high-quality recycled plastic. Regarding current legislative encouragement for recycling, a legally binding directive of the European Union (EU) that all plastic packaging shall be recyclable in a cost-effective manner or reusable by 2030 and aims at making recycling profitable for business. Alongside established mechanical recycling, which is typically accompanied by degraded properties of plastics, alternative methods for recycling plastics are now emerging with the aim of a circular economy in mind, where monomers and oligomers can be repolymerized after purification and used in the same or similar applications as the equivalent virgin polymer. Examples are dissolution/precipitation and upcycling techniques, as well as emerging chemical recycling technologies. Such approaches help to move to a circular economy for plastics, supporting an increase beyond the current 12% by weight of recycled plastics globally, while providing solutions that recycling is not possible, e.g. for sheets, waste streams of contaminated and mixed plastics, as well as multilayer packaging products.
Polystyrene (PS) is a versatile polymer and is widely used in expanded and rigid materials. Despite the versatility of this material, because of the low density and high volume of polystyrene foam, its disposal is problematic, as it heavily affects landfill costs, as well as decreasing landfill space and generating environmental issues. Circular economy procedures such as chemical recycling could be a possible solution. The dissolution with solvents to recycle foamed plastics offers the advantage that all insoluble contaminants can be separated by filtration, including other types of waste and insoluble polymers due to their chemical nature. Applied to the expanded polystyrene (EPS) it allows to significantly reduce its volume without requiring additional energy (98% $L \cdot L^{-1}$ reduction) thus reducing transport costs. Recycling EPS by dissolving in styrene, which is a monomer of polystyrene, is advantageous because it applies the polymerization reaction to incorporate the monomer (solvent) into a polymer chain to avoid the need for polymer-solvent separation. In this study the recycling of expanded polystyrene waste in a closed-loop design using the dissolution/polymerization method was investigated. The aim was to dissolve EPS waste in styrene (its monomer), followed by suspension polymerization of this solution to reobtain PS without the separation of the polymer and the solvent. For this purpose, some experimental parameters were evaluated in order to find the best ones to obtain a recycled polystyrene with properties comparable with the standard polymer. Fourier transform infrared spectroscopy (FTIR), gel permeation chromatography (GPC), thermogravimetric analysis (TGA) were carried out to determine the chemical, thermal and rheological properties of the recycled polymers demonstrating that the recycled material kept its chemical, thermal, and rheological properties.