Solvent-based techniques for recycling of plastics

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The difficulties encountered in plastic recycling are related with the complexity of this waste stream (Kol, Roosen, et al., 2021). Some plastics may be already degraded, which causes complications during mechanical recycling, because if the chains of the polymer are broken, then the polymer has already lost part of its mechanical properties. The presence of multilayer structures also complicates the recycling processes, because the different plastic layers are difficult to separate mechanically and some of these plastics are incompatible with one and another. Contaminants such as paper, inks and food residues can also be present. It is known that these contaminants complicate both mechanical as well as chemical recycling (Kusenberg et al., 2022). Finally, additives that are added during the manufacturing processes of plastics can cause complications during the recycling processes, such as: (i) migration of additives, (ii) degradation of the plastic due to the presence of metal containing additives that can act as pro-oxidants and photo-oxidation catalysts; (iii) leaching and emission of toxic substances to the environment; and (iv) difficulty of recoloration of the recyclate due to the presence of colorants (Hahladakis et al., 2018; Kol, De Somer, et al., 2021).

Solvent-based recycling is a recycling approach that is different from feedstock recycling and depolymerization. It is also sometimes referred to as physical recycling (Schlummer et al., 2020) or solvent-based purification (Crippa et al., 2019). In essence, the composition of the polymer is not changed (Schlummer et al., 2020), which is different from chemical recycling, and the obtained virgin granulates can be introduced in the formulation step of the plastic production lifecycle (Figure 1) (Crippa et al., 2019). The main advantage of solvent-based recycling is the removal of contaminants at the molecular level by using a solvent-based technique (Crippa et al., 2019). This way, the virgin granulates are competitive in terms of quality with virgin material.

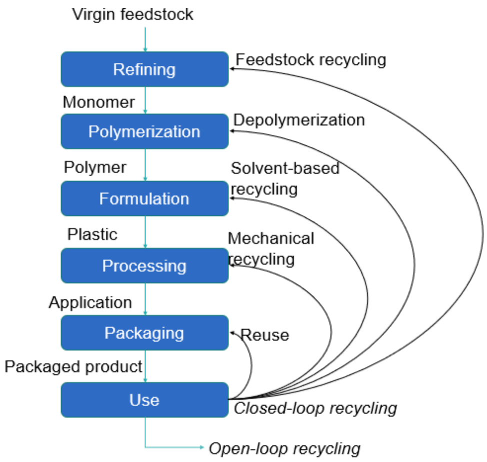

Figure 1. Positioning of plastics recycling process. (Kol, De Somer, et al., 2021)

In this work an overview of solvent-based techniques for closed-loop recycling of plastics is given and the principles of these techniques is explained in detail. In sum, solvent-based recycling techniques are categorized in two groups: solid-liquid extraction methods and the dissolution-precipitation technique (Kol, Roosen, et al., 2021). The advantages and disadvantages of these techniques are discussed and their current existence on the market for the plastic industry is also analysed. It has been concluded that the conventional methods, such as Soxhlet, shake-flask method and ultrasonic extraction methods are low investment techniques, but are time and solvent consuming (Ügdüler et al., 2020). More advanced techniques have been developed, such as the microwave assisted, supercritical fluids and accelerated solvent extraction. These techniques have some advantages over the conventional techniques, such as reduced solvent usage and shorter extraction times or simultaneous extractions are possible, which is the case of the microwave assisted extraction. However, these techniques still require optimization and are not yet available on the market for plastics (Kol, Roosen, et al., 2021). Finally, the dissolution-precipitation technique is based on the principle of dissolving the polymer and adding and antisolvent to recover the polymer by precipitation. The undissolved additives and contaminants can be removed with a solid-liquid separation step (Figure 2) (Kol, De Somer, et al., 2021). One of the advantages of the dissolution-precipitation technique is the selective dissolution of polymer, which enables the selective recovery of different polymers since polymers have different solubilities in solvents. For example, polystyrene dissolves in xylene at 25 ºC and polyolefins dissolve in xylene only at temperatures higher than 70 ºC. There are already on the market operational pilot plants for the recycling of plastics. For example, the CreaSolv® Technology by Fraunhofer Institute focuses on the removal of flame retardants and plasticizers from different polymers. Polystyvert is working on the recycling of polystyrene and PureCycle Technologies recovers polypropylene (Kol, De Somer, et al., 2021).

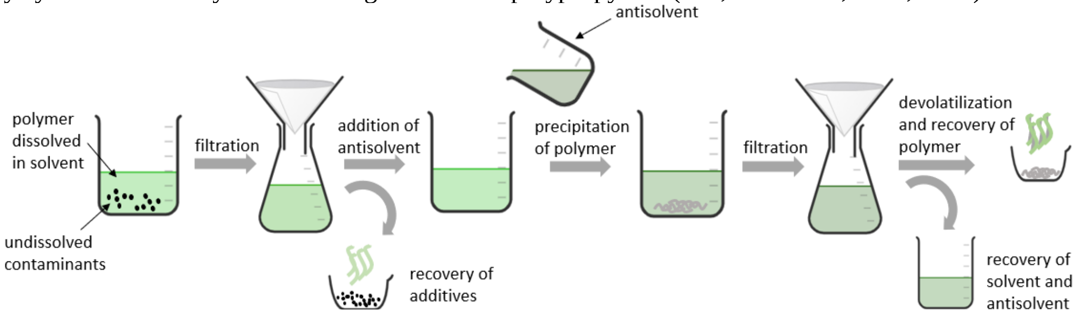

Figure 2. Simplified schematic of the dissolution-precipitation technique (Kol, De Somer, et al., 2021).

To conclude, solvent-based recycling is a promising approach to close the loop of plastics, as it allows the removal of contaminants and additives that difficult the recycling processes. Improvement of solvent-based techniques and investigation for industrial implementation is still required, but these techniques show a great potential towards upcycling of plastic waste. In this presentation we will focus on the state-of-the-art in solvent based recycling of waste plastics, together with some of their potential challenges and opportunities. Apart from literature, this presentation will also give some examples of lab experiments highlighting the power of this technique to remove impurities such as dyes and pigments.

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