Advancing the Recycling of Textiles via Efficient Sorting and Molecular Upcycling

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Abstract:

The growing textile industry is producing waste at an alarming rate. Global fiber production reached an all-time high of 124 million tonnes in 2023.[1] Waste management of textiles has been rather ineffective. 75% of materials used in clothing are landfilled or incinerated, and 23% of discarded clothes are collected for recycling, however, less than 1% of the recovered fibers are used to produce new fabric.[2]

Spurred by the urgency of reducing the environmental footprint of textiles and recovering value from used textiles, this paper highlights challenges and recent advances to (i) identify and sort textiles at the macroscopic level (i.e., clothing items) and (ii) separate blended textiles at the molecular scale (i.e., cotton and polyester fibers). The former is a key component of mechanical recycling, while the latter falls under chemical or molecular recycling.[3]

The recycling of textiles is impeded largely by a lack of actionable information about the content of the fabric, in turn, caused by insufficient capabilities of current spectroscopic identification techniques. High-throughput, automated sorting is developed through the utilization of visible and infrared spectroscopy, including hyperspectral methods, combined with machine learning (ML) [4] for rapid identification of textile composition. This will enable the subsequent separation of higher and lower value textile grades, and identify "disruptors" for fiber-to-fiber textile recycling, such as flame retardants and water repellent finishes, that are typically difficult to detect.

Blended or mixed textiles pose challenges for mechanical recycling which cannot separate fibers from the blend. However, separation of fiber blends can be achieved by selectively dissolving or depolymerizing specific polymers in the blend.[5] Specifically, the separation of cotton and polyester through dissolution or hydrolysis is discussed, and the removal from other fibers of elastane though its selective degradation or dissolution.

The developments presented here can promote sustainable practices in the textile and waste management sectors, hence facilitating the shift towards a circular economy.

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