Polymer Differentiation with Computed Tomography: Opportunities and Limitations

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Introduction

In the context of polymer recycling, differentiation and analysis of various polymer types are crucial for effective material separation and reuse. Recycling polymers typically involves the complex task of separating individual materials from mixed polymer waste, since mixed plastics are still a big challenge for the recycling process. This study explores the effectiveness of computed tomography (CT) in distinguishing between different types of polymers based on their density and elemental composition, facilitating more efficient recycling processes.

Materials and Methods

A specimen consisting of six stacked polymer sheets, each approximately 500 µm thick, was prepared by Borealis Polyolefine GmbH for analysis. The polymers included polypropylene (PP), polyethylene (PE), polystyrene (PS), polyamide (PA), polyetheretherketone (PEEK) and polyethylene terephthalate (PET). Two different CT devices, the GE Nanotom 180NF and the RX Solutions Easytom 160, were used with specific parameters and varying voltage settings. Simulations with the in-house software SimCT complemented the experimental data, focusing on polychromatic and monochromatic X-rays. Grey values from scans and simulations were analyzed to determine the distinguishability of polymers based on their attenuation properties.

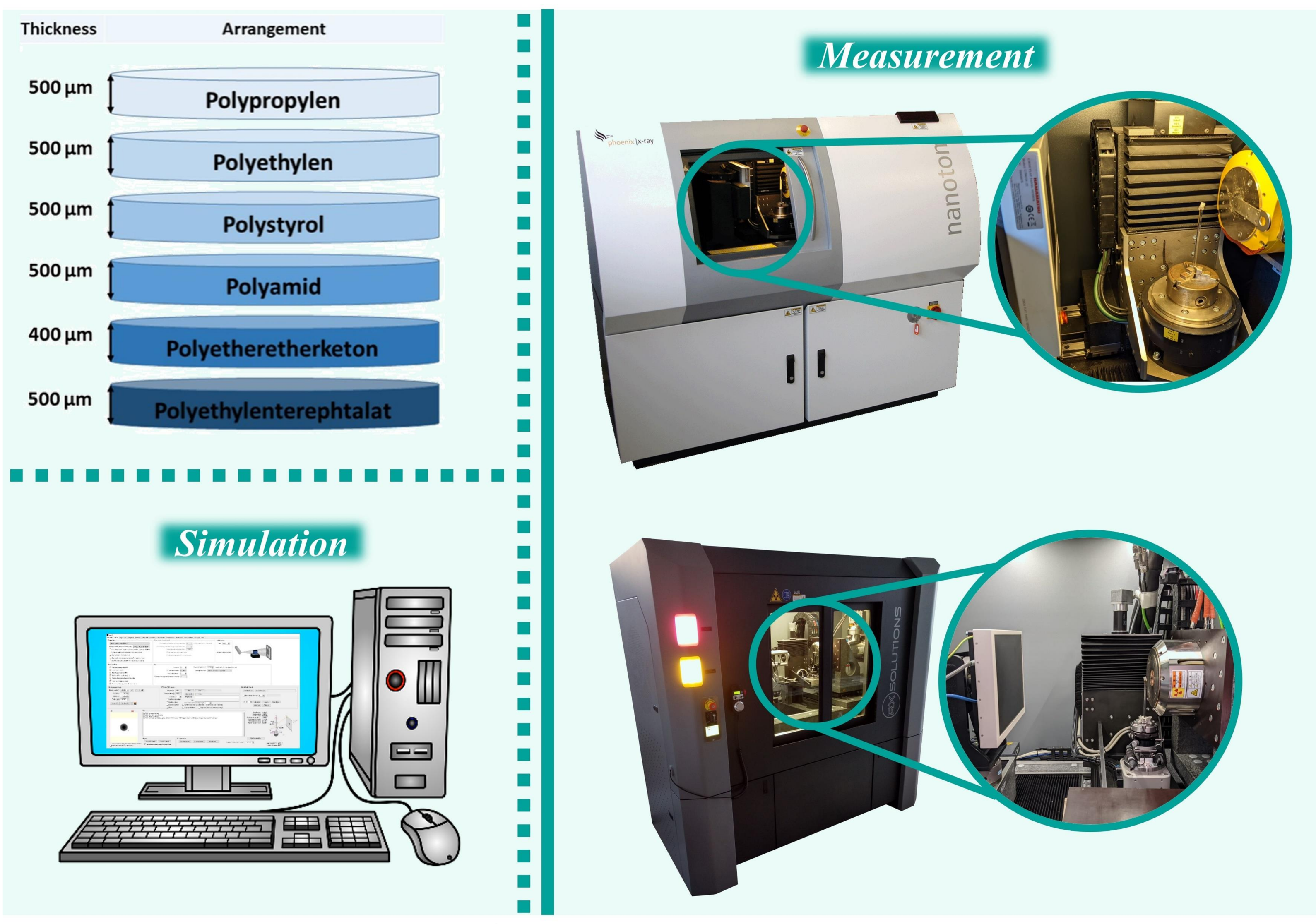

Figure 1: Schematic representation of the test specimen, simulation, and measurement methodologies

Results and Discussion

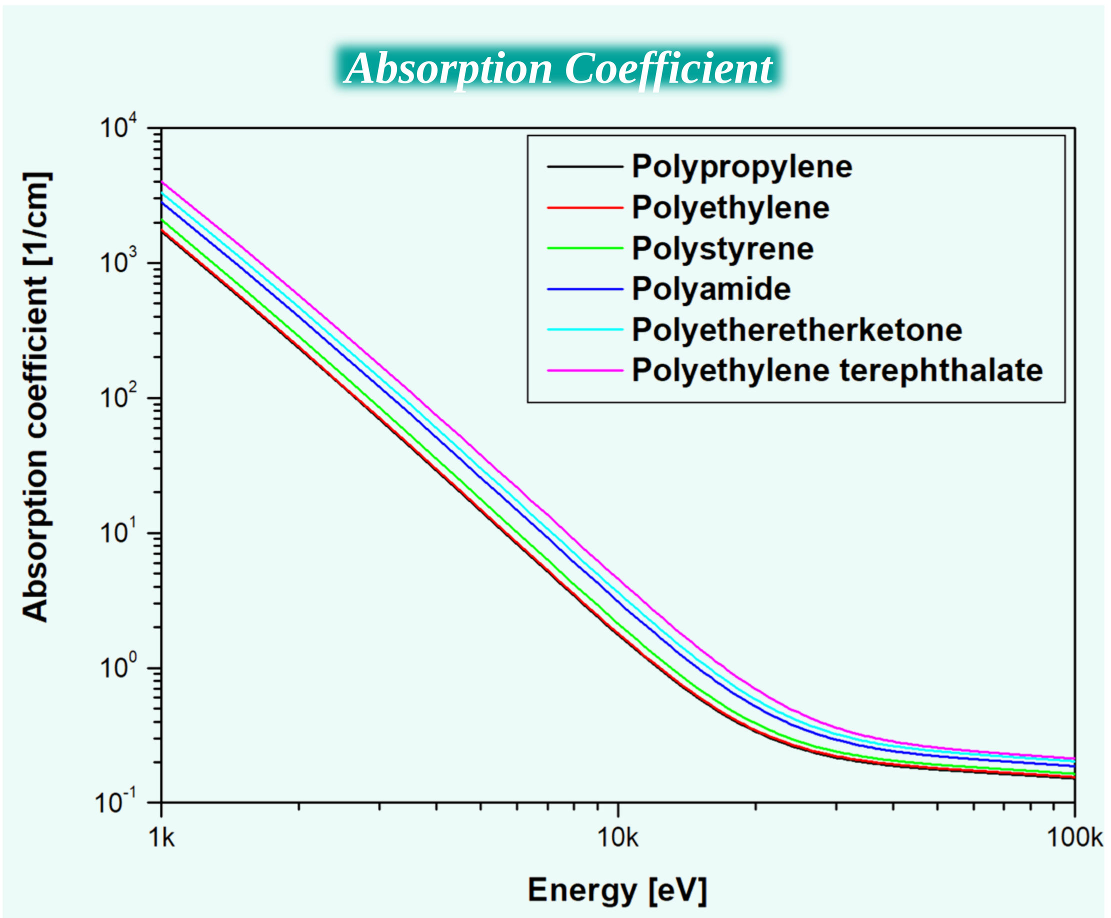

Figure 2: Absorption coefficients of the analyzed polymers

Generally, the average grey values are increasing with increasing density. This is due to an increase of the absorption coefficient of X-rays as shown for the analyzed polymers in figure 2. Normalized grey values of scans and simulations are presented in figure 3. The steepest slope is present for the lowest voltage, giving the greatest grey value difference – or in other words contrast – between the different polymer classes. With increasing voltage, the contrast is decreased, making polymer identification more challenging. Corresponding to this parameter study the lowest possible voltage would be recommended for polymer differentiation. Therefore, only the lower voltages were considered for the CT measurements. As predicted by simulation, the steepest slope from PP to PET is present for the measurements with the lowest voltage. Further, grey value differences are great enough for differentiation of polymer classes except for PP, PE in all cases; and PS when higher voltages are applied. The use of monochromatic X-rays in simulations showed promise for improving contrast by absence of noise, especially for lower energies.

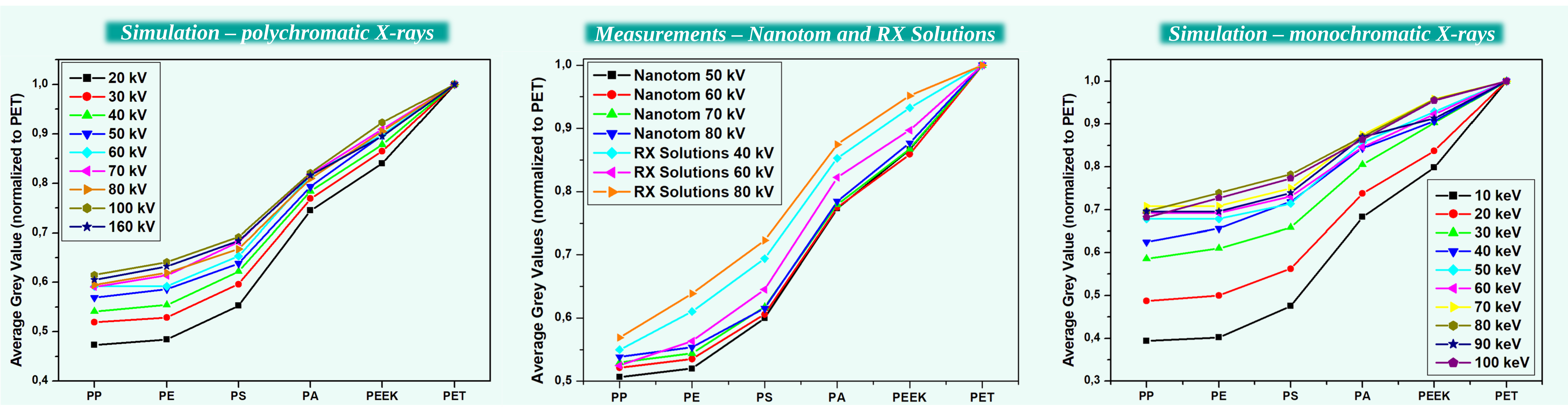

Figure 3: Normalized grey values of the different polymers for simulation with polychromatic X-rays (left), CT measurements (middle), and simulation with monochromatic X-rays (right)

Conclusion

This poster demonstrates the potential of using computed tomography to differentiate between various polymer classes. However, the differentiation between polymers with very similar densities and elemental composition, remains challenging. The use of monochromatic X-rays in simulations showed promise for improving contrast by absence of noise, suggesting that further improvement of CT technology, such as the usage of photon-counting detectors, could enhance polymer classification.

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