

## **A Machine Learning Driven Ultrafast Mid-Infrared Spectroscopic System for Mixed Plastic Characterization**

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1. Emerging Recovery & Recycling Technologies
2. Technologies for Transforming Materials Recovery Facilities

Abstract:

The U.S. Environmental Protection Agency estimates that over 35.6 million tons of plastic waste are generated annually in the United States, yet only 8.7% is recycled, with approximately 75% ending up in landfills. Among the landfilled plastic waste, 15%—equivalent to more than 2.5 million tons annually—comprise black and dark-colored plastics. This high disposal rate is primarily due to the inability of existing optical sensors, such as near-infrared (NIR) and camera systems used in Material Recovery Facilities, to detect black plastics due to their low reflectivity in the near-visible wavelength range. Mid-infrared (MIR) technology has the potential to overcome this limitation by providing accurate compositional information independent of plastic color. However, traditional MIR systems suffer from slow measurement speeds, limiting their applicability in industrial settings. To address this challenge, we developed a ultra high-speed MIR characterization system capable of measuring of up 400-10,000 infrared spectra per second, integrated with a belt conveyor operating at 20-600 feet per minute. This innovation bridges the gap between laboratory-grade MIR analysis and the operational requirements of industrial recycling facilities. To ensure reliable performance despite the low signal-to-noise ratio inherent to high-speed MIR measurements, we implemented robust wavelet data preprocessing techniques. Additionally, we developed a lightweight machine learning (ML) model that achieves over 95%-99% accuracy in characterizing mixed plastic waste, including black plastics. Our ML model is designed for efficiency and operation without reliance on large-scale data centers, enabling seamless integration into industrial control systems. By facilitating the accurate identification and recovery of black plastics, our MIR characterization system offers a practical solution to increase recycling rates and reduce landfill waste. This innovation supports the

development of a sustainable and circular economy in plastic recycling, addressing critical environmental challenges and unlocking new opportunities for resource recovery.