The Digital Revolution of Recycled Plastics: Materials Informatics Driving the Circular Economy

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Abstract

Recycled plastics are becoming essential to achieving a circular economy as concerns over waste, resource constraints, and carbon emissions intensify. Among them, recycled polypropylene (PP) is gaining particular importance for automotive and industrial applications, yet significant challenges remain in ensuring consistent quality, understanding degradation, and enabling high-value reuse. Digital technologies and materials informatics now offer powerful pathways to overcome these limitations.

The SIP-Lab at the National Institute for Materials Science (NIMS) is advancing a data-driven framework for recycled plastics by leveraging the world's largest standardized PP database, originally developed through the Materials Open Platform (MOP). This foundation enables systematic acquisition and predictive modeling of structural, thermal, and mechanical properties of recycled PP.

Key digital tools—including the DICE materials data platform and the cloud-based Research Data Express (RDE)—support high-throughput data management and machine-learning analysis. Recent analytical innovations such as reference-free quantitative mass spectrometry (RQMS) provide detailed insight into chemical degradation and additive loss, while AI analysis of melt-viscosity time-series data enables non-destructive, real-time quality classification.

Together, these approaches are redefining recycled plastics as data-rich, engineerable materials. By integrating materials informatics and advanced analytics, the digital revolution is accelerating the development of high-performance recycled plastics and supporting the transition toward a sustainable circular materials economy.

Keywords: Circular economy, Recycle, Polymer database, machine learning, and Autonomous laboratory

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