A NEW PARADIGM FOR PLASTIC RECYCLING

OCTOBER 29-30, THURSDAY-FRIDAY,
MICHIGAN TECHNOLOGICAL UNIVERSITY

SYMPOSIUM ON SOLVENT-BASED PLASTIC RECYCLING TECHNOLOGIES

1885

Michigan Technological University

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Reid Van Lehn
Professor, Chemical and Biological Engineering UW-Madison

We are thrilled to host you at Michigan Tech for the first Symposium on Solvent-Based Plastic Recycling Technologies to explore the future of advanced recycling. We gathered experts in solvent-based plastic recycling from academia, municipalities, funding agencies, private foundations, national labs, and industry to discuss state-of-the-art solvent-based recycling. We will also inaugurate and visit the MTU pilot facility at the Advanced Power Systems (APS) Labs.

Travel

October is peak travel season in Michigan's Upper Peninsula due to fall foliage. We strongly recommend booking airfare and lodging as early as possible.

- Local airport: Houghton County Memorial Airport (CMX).
- Alternative airports:
  Marquette Swayer Regional Airport (MQT).
  Ford Airport-Iron Mountain/Kingsford (IMT).
  Both are approximately 2 hours away from Houghton.
- Driving: May be convenient option for some attendees; free parking will be available at the conference venue.

Location and Lodging

The Symposium on Solvent-Based Plastic Recycling Technologies will be hosted at Michigan Tech in scenic Houghton, Michigan, located along the picturesque Portage Lake near Lake Superior. Our conference sessions will be held at the **Alumni Center (ATDC), Ford Conference Room 101**.

Michigan Tech is rooted in a strong tradition of hands-on education and boasts a broad alumni base across Michigan, Wisconsin, Minnesota, and all around the world. The surrounding Keweenaw Peninsula offers a variety of lodging options —from well-known hotel chains to cozy local cabins and vacation rentals. Lodging fills up quickly during peak times, so we encourage you to book early to secure your stay! This link might help you in finding a hotel: https://www.mtu.edu/admissions/visit/lodging/

THURSDAY, OCTOBER 29, 2026

8:00 - 9:00 am	**Registration & Gathering**
9:00 - 9:30 am	**Welcome and Greetings**
9:30-10:00 am	**Opening Remarks** **George Huber: The Inception of STRAP** **Magdi Azer: Remade Role in Plastic Recycling**
	Plenary, Chaired by Ezra Bar-Ziv
10:00 - 10:30 am	Jan-Georg Rosenboom, MacroCycle, Solvent-Based Plastic Recycling: From the Lab to Market Deployment, **Symposium Plenary**
10:30 - 10:45 am	**Coffee Break**
10:45 am - 12:30 pm	**Solvents for Plastic Recycling, Chaired by George Huber** Reid Van Lehn, University of Wisconsin-Madison, The Theory Behind Solvent-Based Technologies for Plastic Recycling, **Topical Plenary** Katrina Knauer, National Laboratory of the Rockies, Bio-Based Solvents for Dissolution-Based Plastic Recycling: Opportunities, Challenges, and Sustainability Impacts, **Topical Plenary** Victor Zavala, University of Wisconsin-Madison, AI/ML Techniques for Solvent-Based Separations Jason Bara, The University of Alabama, Green Solvents Applied to PVC Waste: Simultaneous Additive Removal and Molecular Weight Fractionation as a Gateway to Chemical Upcycling
12:30 - 1:30 pm	**Lunch**
1:30 - 2:15 pm	**Feedstock and Pre-Processing, Chaired by Wei Wei** Jordan Klinger, Idaho National Labs, Feedstock Pre-Processing Lily Callen, University of Wisconsin-Madison, Mechanical Fractionation Pretreatment for Polymer Recovery from MSW
2:15 - 3:45 pm	**Scaling Up, Chaired by Ellen Lee** Fei Long, Michigan Tech, From Laboratory Research to Pilot-Scale Deployment: Advancing STRAP for Circular Plastics Manufacturing, **Topical Plenary** Zach Wagner, Michigan Tech, Fast Dissolution for Up-Scale in STRAP Faith Gaertner, Michigan Tech, Filtration and Precipitation in STRAP Rebecca G. Ong, Michigan Tech, Scale-up of Ammonia-Based Deconstruction to Enable Media-Free Biological Upcycling of Waste Plastics, Multilayered Materials, and Textiles
3:45 - 4:00 pm	**Coffee Break**
4:00 - 6:30 pm	**Tour of the STRAP Pilot System at the APS Lab**
6:30 -8:30 pm	**Dinner**

FRIDAY, OCTOBER 30, 2026

8:00 - 9:00 am	**Gathering**
9:00 - 10:00 am	**Recycling of Multi-Layer Films, Chaired by Aurora del Carmen Munguía-López** Brent Martin, Amcor, The Potential Use of Solvent-Based Technologies for Plastic Recycling in the Packaging Industry Tushar, University of Wisconsin-Madison, Recycling of Single-Use Multilayer Plastics for Biomanufacturing with Solvent-Targeted Recovery and Precipitation Paschalis Alexandridis, University at Buffalo, Delamination Recycling of Multilayer Plastic Films: Solvent-assisted Separation and Recovery of Intact Solid Polyolefins
10:00 - 10:30 am	**Coffee Break**
10:30 am - 12:00 pm	**Process Analysis, TEA, LCA, Chaired by Victor Zavala** Styliana Avraamidou, University of Wisconsin-Madison, A Process-Modeling Platform for STRAP: TEA, LCA, and System Integration, **Topical Plenary** Aurora del Carmen Munguía-López, University at Buffalo, Systems Engineering Approaches for Sustainable Plastic Management Vinh Nguyen, Michigan Tech, AI Agent-Enabled Digital Twin for STRAP Process Control Elizaveta Radkevich, University of Wisconsin-Madison, Review of Solvent-Based Processes and Current State of the Field
12:00 - 1:00 pm	**Lunch**
1:00-2:00 pm	**Polyolefins Recycling, Chaired by Paschalis Alexandridis** Ellen Lee, Ford Motor Company, Automotive Industry Needs for Plastics Recycling Marina Tsianou, University at Buffalo, Dissolution-Precipitation Separation of Polyolefins for Plastics Recycling Applications Armando G. McDonald, University of Idaho, Polyolefin Recovery from Municipal Solid Waste by Solvent Extraction
2:00 - 3:30 pm	**Decontamination and Characterization, Chaired by Fei Long** Wei Wei, Michigan Tech, Integrated Characterization of Solvent-Recovered Polymer Streams from STRAP Processing Bassam Abdelghani, Michigan Tech, On-Line Characterization of Plastic Wastes Yucheng Peng, Auburn University, Reclaiming Polyethylene from a Multilayer Plastic Packaging Structure for Property Characterization Varsha Mahendran, University of Wisconsin-Madison, Getters: A Novel Approach to Recycle High-Quality Polypropylene from Single-Use Technology (SUT) Waste Streams
3:30 - 4:00 pm	**Summary and Adjourn**

Presentations

Presenter	Title
Jan-Georg Rosenboom	SolvoGenesis Recycling for Textiles: From the Lab to Market Deployment
Reid Van Lehn	Theory Behind Solvent-Based Technologies for Plastic Recycling
Katrina Knauer	Bio-Based Solvents for Dissolution-Based Plastic Recycling: Opportunities, Challenges, and Sustainability Impacts
Victor Zavala	AI/ML Techniques for Solvent-Based Separations
Jason Bara	Green Solvents Applied to PVC Waste: Simultaneous Additive Removal and Molecular Weight Fractionation as a Gateway to Chemical Upcycling
Jordan Klinger	From Waste to Feedstock: Advanced Preprocessing and Fractionation
Lily Callen	Mechanical Fractionation Pretreatment for Polymer Recovery from MSW
Fei Long	From Laboratory Research to Pilot-Scale: Advancing STRAP for Circular Plastics Manufacturing
Zach Wagner	Material Handling, Dissolution, Filtration, & Solvent Recovery for STRAP Pilot System
Faith Gaertner	Dissolution, Decontamination, and Precipitation for the STRAP Pilot System
Rebecca Ong	Scale-up of Ammonia-Based Deconstruction to Enable Media-Free Biological Upcycling of Waste Plastics, Multilayered Materials, and Textiles
Brent Martin	Potential Use of Solvent-Based Technologies for Plastic Recycling for Packaging
Tushar	Recycling of Single-Use Multilayer Plastics for Biomanufacturing with STRAP
Paschalis Alexandridis	Delamination Recycling of Multilayer Plastic Films: Solvent-assisted Separation and Recovery of Intact Solid Polyolefins
Styliana Avraamidou	A Process-Modeling Platform for STRAP: TEA, LCA, and System Integration
Aurora del Carmen Munguía-López	Systems Engineering Approaches for Sustainable Plastic Management
Vinh Nguyen	AI Agent-Enabled Digital Twin for STRAP Process Control
Elizaveta Radkevich	Review of Solvent-Based Technologies and Current State of the Field
Ellen Lee	Automotive Industry Needs for Transition to a More Circular Economy
Marina Tsianou	Dissolution-Precipitation Separation of Polyolefins for Plastics Recycling Applications
Armando McDonald	Polyolefin Recovery from Municipal Solid Waste by Solvent Extraction
Wei Wei	Integrated Characterization of Solvent-Recovered Polymer Streams from STRAP Processing
Bassam Abdelghani	On-Line, Real-Time, Mid-IR Spectroscopy for Plastic Identification Setting
Yucheng Peng	Reclaiming PE from a Multilayer Plastic Packaging Structure for Characterization
Varsha Mahendran	A Novel Approach to Recycle High-Quality PP from Single-Use Waste Streams

SolvoGenesis Recycling for Textiles: From the Lab to Market Deployment

Jan-Georg Rosenboom
MacroCycle

ABSTRACT

Textiles are the fastest growing waste stream in the United States, with the vast majority of textile waste landfilled, incinerated or shipped to less developed nations. At the same time, virgin PET production is expected to increase from currently ~75 MT/y to >100 MT/y by 2030, contributing to the 6-8% of global CO_2 emissions by the textile industry. Polyester-based textiles are inherently blended with cotton, elastane, nylon and contain dyes, finishes, zippers and buttons, all of which make these materials impossible to recycle through traditional (thermos-) mechanical means. This global waste and energy problem has caught widespread attention from consumers, government and investors. Depolymerization Recycling provides an alternative pathway through monomers, however, these processes are relatively complex, energy intensive, and not resilient to several disrupting impurities found in textile waste. Dissolution Recycling presents a new technology frontier that can unlock low-cost and impurity-resilient textile recycling. MIT startup company MacroCycle is commercializing and scaling a new process termed SolvoGenesis™ (instead of Solvo-Lysis), which produces virgin-grade recycled PET from blended textile waste using highly selective solvent systems and macrocyclic polymerization chemistry. TEA shows an energy demand reduction of around 80% compared with virgin PET, paving a path for cost competitiveness with oil-based resin and financeable factory builds. Yet, the path from promising laboratory results to industrial scale is long and non-trivial. This talk will explore MacroCycle's tech commercialization journey through technology pivots, fundraising strategies, customer discovery, feedstock variability and scaling challenges.

Theory Behind Solvent-Based Technologies for Plastic Recycling

Reid C Van Lehn
University of Wisconsin-Madison

ABSTRACT

Globally, over 400 million metric tons of plastic are produced per year. Most plastic waste consists of complex mixtures of polymers, intentionally added substances, and non-intentionally added substances (*i.e.*, contaminants). Solvent-based recycling technologies, such as the Solvent-Targeted Recovery and Precipitation (STRAP), exhibit great potential for the recovery of high-quality resins from these complex feedstocks. In this talk, I will discuss the theoretical basis of STRAP and why solvent-based technologies are well-suited for purifying compositionally complex feedstocks. I will focus on the thermodynamics of multicomponent polymer solutions and discuss the chemical and physical parameters that influence polymer and contaminant solubility and partitioning. Based on this thermodynamic framework, I will describe computational tools for guiding solvent selection and optimizing process parameters, such as temperature. Finally, I will present examples of how such tools have been used to tailor STRAP to various feedstocks, such as flexible packaging waste.

Bio-Based Solvents for Dissolution-Based Plastic Recycling: Opportunities, Challenges, and Sustainability Impacts

Katrina Knauer
National Laboratory of the Rockies

ABSTRACT

The growing accumulation of plastic waste has intensified interest in advanced recycling technologies capable of recovering high-quality polymers from complex waste streams. Dissolution-based recycling has emerged as a promising approach because it enables the selective recovery of polymers while preserving molecular weight and material performance. However, the environmental and economic viability of these processes is strongly influenced by solvent selection. This presentation will explore the opportunities for incorporating bio-based solvents into dissolution-based plastic recycling systems, highlighting how renewable solvent platforms may improve process sustainability while maintaining effective polymer dissolution and purification performance. The talk will examine key solvent-property relationships that govern polymer selectivity, recovery efficiency, solvent recyclability, and process integration across a range of commodity plastics. Particular emphasis will be placed on emerging bio-derived solvent families and their potential to reduce fossil resource consumption, toxicity concerns, and lifecycle greenhouse gas emissions relative to conventional petrochemical solvents. To evaluate the practical feasibility of these approaches, the presentation will also discuss techno-economic analysis (TEA) and life cycle assessment (LCA) results for representative dissolution-based recycling pathways. These analyses identify the major cost and environmental drivers associated with solvent production, recovery, energy consumption, and waste management. By integrating solvent design with systems-level sustainability metrics, this work provides a framework for guiding the development of economically competitive and environmentally beneficial dissolution-based plastic recycling technologies.

AI/ML Techniques for Solvent-Based Separations

Victor Zavala
University of Wisconsin, Madison

ABSTRACT

In this talk we provide an overview of different artificial intelligence and machine learning (AI/ML) techniques applied to the analysis and design of solvent-based separation technologies. Specifically, we discuss how to use ML and optimization techniques for navigating vast chemical design spaces that help identify suitable solvents to extract target contaminants. Specifically, we show how these techniques can be used to identify solvents capable of capturing PFAS compounds. We also discuss how to use ML techniques to guide experimental procedures to identify solvent mixtures to recover target products. Specifically, we show how to combine Bayesian Optimization and rigorous thermodynamics models to quickly identify solvent mixtures. Finally, we discuss how to use AI tools, particularly large language models, to create agents that help automate the analysis and design of solvent-based separation processes. These agents are powerful in that they combine databases, thermodynamic models, literature, and process simulators to conduct automated design.

Green Solvents Applied to PVC Waste: Simultaneous Additive Removal and Molecular Weight Fractionation as a Gateway to Chemical Upcycling

Jason E. Bara, Pravin S. Shinde, Jaewoo Choi, Ali Al Alshaikh
The University of Alabama

ABSTRACT

Polyvinyl chloride (PVC) is the third most produced synthetic polymer globally yet among the least recycled, owing to the complexity introduced by its chlorine content and the diverse additives — plasticizers, stabilizers, and fillers — compounded into commercial formulations. These additives present a fundamental barrier to conventional mechanical recycling by contaminating the recovered polymer matrix. We recently reported that green solvents, specifically acetone and methanol mixtures, provide a simple and scalable route to simultaneously remove additives and separate PVC by molecular weight (MW), functioning as a practical first step in a chemical upcycling workflow. Acetone:methanol (Ace:MeOH) solvent systems selectively dissolve low-MW PVC fractions from commercial K50 and K65 resins at ambient temperature, leaving the bulk high-MW resin undissolved. Solvent composition directly controls the extracted MW which we have correlated to Hansen Solubility Parameters (HSPs). For example, an 80:20 Ace:MeOH ratio yields Mw = 14.7 kDa (Đ = 1.46), while pure Ace yields Mw = 26.3 kDa (Đ = 1.53), as characterized by GPC. Simultaneously, inorganic additives such as $CaCO_3$ remain insoluble and are removed by simple filtration, while plasticizers partition into the organic phase and are recoverable by extraction/precipitation. Fractionation strategies can thus deliver defined, well-behaved low-MW feedstocks for downstream chemical transformation. These low-MW fractions can be subjected to controlled dehydrochlorination followed by chain cleavage to yield ultra-low-MW chains that can be directly used as plasticizers for PVC.

From Waste to Feedstock: Advanced Preprocessing and Fractionation

Jordan Klinger
Idaho National Laboratory

ABSTRACT

The Bioenergy Feedstock National User Facility (BFNUF) at Idaho National Laboratory (INL) is at the forefront of developing and demonstrating advanced preprocessing solutions for diverse feedstocks, including municipal solid waste (MSW), biomass, e-scrap, and secondary mining residues. This presentation will highlight the BFNUF's unique capabilities for mechanical and advanced preprocessing, with a primary focus on MSW as a challenging, heterogeneous resource. We will discuss how state-of-the-art size reduction, classification, and fractionation strategies can transform non-recyclable MSW into consistent, high-quality feedstocks for biorefinery applications. Recent research at INL demonstrates that mechanical preprocessing not only improves the physical and chemical uniformity of MSW, reducing variability in properties such as bulk density, ash content, and heating value, but also enhances its combustion and flow characteristics, which are critical for reliable biorefinery operation. The talk will further explore opportunities in feedstock fractionation and valorization, including the separation of plastics, fibers, and inorganics, and how these approaches can unlock new value streams and support circular economy objectives. Finally, we will outline future directions in integrating advanced separation and mild chemical and thermal preprocessing to further improve feedstock quality and enable the sustainable valorization of MSW and related waste streams.

Mechanical Fractionation Pretreatment for Polymer Recovery from MSW

Lily Callen,[1] Elli Wagner,[2] Fei Long,[2] Ezra Bar-Ziv,[2] and George Huber[1]
[1]University of Wisconsin–Madison, [2]Michigan Technological University

ABSTRACT

Municipal solid waste (MSW) generation poses a global challenge to reducing emissions and achieving renewable energy targets. The residual waste stream generated by material recovery facilities (MRF) represents a major source of MSW that is primarily landfilled in the United States. Landfilling represents a permanent loss of valuable resources, highlighting the need for new waste-management strategies that can separate both polymeric and biogenic components at high purity. To address this issue, we developed an integrated process that combines mechanical fractionation of MRF residues with a plastic dissolution process, Solvent-Targeted Recovery and Precipitation (STRAP), to produce purified plastic, biogenic, and inorganic material streams. High-shear grinding and vibro-sifting facilitated the separation of MSW into five size fractions. Characterization of the fractions with microscopy and elemental analysis revealed the materials concentrated into plastic, biogenic, and mineral-rich fractions. Heat content reveals that plastics are concentrated in the larger size fractions. Chlorine and ash analyses further indicated that chlorinated resins and ash could be effectively isolated into distinct streams. STRAP selectively recovered polyolefins from the MRF residue, and the resulting polymers were characterized both thermally and mechanically to determine their composition, residual solvent content, and mechanical properties. When applied on MRF residue, the combined mechanical fractionation pretreatment and STRAP process successfully generated a purified polyolefin stream alongside biogenic and inorganic fractions suitable for renewable energy production and soil remediation, respectively.

From Laboratory Research to Pilot-Scale: Advancing STRAP for Circular Plastics Manufacturing

Fei Long
Michigan Technological University

ABSTRACT

Solvent-Targeted Recovery and Precipitation (STRAP) has emerged as a promising approach for recovering high-purity polymers from complex plastic waste streams that are difficult to recycle using conventional mechanical and chemical processes. By selectively dissolving and recovering individual polymers, STRAP can produce recycled resins with properties comparable to virgin materials while enabling the recycling of multilayer films, mixed plastics, and contaminated waste streams. Over the past decade, researchers at the University of Wisconsin–Madison and Michigan Technological University have advanced STRAP from fundamental polymer-solvent science to an integrated recycling platform. This presentation will highlight recent progress in scaling the technology from laboratory demonstrations to pilot-scale operation, including innovations in dissolution, solid-liquid separation, contaminant removal, precipitation, and solvent recovery. The commissioning of the MTU STRAP pilot facility represents an important milestone in bridging fundamental research and industrial deployment of solvent-based recycling technologies. The presentation will discuss future research directions, scale-up opportunities, and collaborative pathways needed to accelerate commercialization and expand the role of solvent-based recycling within a circular plastics economy.

Solid Material Handling, Dissolution, Filtration, and Solvent Recovery for the STRAP Pilot System

Zach Wagner,[1] Faith Gaertner,[1] Charles Granger,[2] Fei Long,[1] George Huber,[2] Ezra Bar-Ziv[1]
[1]Michigan Technological University, [2]University of Wisconsin-Madison

ABSTRACT

The Solvent Target Recovery and Precipitation (STRAP) process is a cutting edge, solvent-based recycling technology for polymer recovery from mixed waste or multi-layer plastic waste streams. STRAP by selectively extracting the target polymer by exposing the waste to a solvent only the targeted polymer is soluble. The polymer solution is separated from the non-dissolved portion and cleaned through a series of mechanical filtration. The temperature of the polymer solution is then controlled to precipitate the polymer back into a pure, solid form. We have developed a 25kg/h STRAP Pilot-Scale Unit (PSU) to demonstrate the scalability and efficiency of this process. The PSU consists of several operational sub processes: (i) solid material conveying; (ii) dissolution and separation; (iii) candle filtration; (iv) solid material drying; (v) precipitation; (vi) vacuum solvent recovery; (vii) outgassing extrusion; (vii) nitrogen generation; (ix) heating oil; (x) chilled water. The PSU is designed to work in a hybrid batch-continuous operation. The solid material conveying system was designed to facilitate the transition of continuous-batch solid handling into to accommodate the batch-style dissolution process operating at 25kg/h. The dissolution system was designed to generate high-shear and turbulent flow fields during mixing to facilitate enhanced dissolution to give dissolution time <30s. The separation of non-dissolved solids from the solution is performed inside of a centrifugal sifter at speeds 800-1800rpm to give a processing time <3min. The wet non-dissolved solids are sent to an oil heated twin screw auger conveyor where the end material will have a solvent content <0.5% and the solvent vapors will be condensed and collected facilitating a 99.9% solvent recovery process wide.

Dissolution, Decontamination, and Precipitation for the STRAP Pilot System

Faith Gaertner,[1] Zach Wagner,[1] Charles Granger,[2] Fei Long,[1] George Huber,[2] Ezra Bar-Ziv[1]
[1]Michigan Technological University, [2]University of Wisconsin-Madison

ABSTRACT

STRAP is a solvent-based recycling technology for recovery of pure resins from mixed waste streams. MTU built a STRAP pilot system that operates from material handling to the end-product in the shape of pellets. We will discuss the following critical components of the STRAP pilot system: (i) dissolution; (ii) decontamination; and (iii) precipitation. We have carried out pilot scale dissolution experiments using a PP-rich waste stream and have extracted pure and color-free PP. This product had properties and features similar to virgin-PP. We also demonstrated decontamination of polymer-solution particulates within the pigment and reinforcement size range via filtration. Demonstrations with the use of activated carbon adsorption provide further color removal of soluble colorants and allow for the production of color-free resins. We have developed a unique precipitation system that comprises fast precipitation, solvent filtration, resin melting, and solvent removal to achieve rapid cooling-based precipitation.

Scale-up of Ammonia-Based Deconstruction to Enable Media-Free Biological Upcycling of Waste Plastics, Multilayered Materials, and Textiles

Rebecca G. Ong, Ruochen Wu, M. Aamir Bashir, Kaushik Baruah, Elizabeth Schumann, Libby Umlor, Joshua Oetting, Kieran Vacek, Andrew Brenner, Kevin Garland, Sean Lynn, Andrea Senyk, Sulihat Aloba, Hunter Stoddard, Laura Schaerer, Daniel Kulas, Lindsay Putman, Joshua Pearce, David Shonnard, and Stephen Techtmann
Michigan Technological University

ABSTRACT

Although pure biological recycling of plastics to monomers using enzymes has made significant strides in recent years, the major downside of this approach is the slow time scale for polymer depolymerization. To overcome this issue, our team has coupled more rapid chemical depolymerization using ammonium hydroxide with biological conversion of resulting monomers to produce novel products that can only be made using biology, such as food and animal feed. A key benefit of using an ammonia-based deconstruction step is that it is possible to fully replace microbial media with neutralized liquid product from chemical deconstruction of polymers, supplemented with minor amounts of essential minerals. This process has been successfully used to deconstruct various polymers including PET, polyurethane foams, PLA, and synthetic textiles, and selectively solubilizes the polyester components from multilayered metalized films, typically achieving >95% theoretical solubilization. Over the past five years we have scaled up the process from 16 mL glass vials through various iterations of custom reactors, recently demonstrating simultaneous deconstruction of 600 g of mixed waste in a custom dual reactor skid. This process selectively deconstructs and solubilizes monomers suitable for microbial conversion to single cell protein and generates a higher quality solid product suitable for pyrolysis to fuels and lubricant precursors.

The Potential Use of Solvent-Based Technologies for Plastic Recycling in the Packaging Industry

Brent Martin
Amcor

ABSTRACT

For decades, the flexible packaging industry has advanced the development of highly engineered multi-layer polymeric films to satisfy the needs of the marketplace. The demand to make these structures recyclable is a more recent addition to the list of performance requirements which has introduced significant limitations in packaging design. Today's recycling infrastructure relies heavily upon mechanical methods which do not tolerate material incompatibilities and this blocks many high-performance polymers from use in recycle-ready structures. Solvent-based recycling technologies would reenable the combination of varying polymer types to produce high-performing and low cost packaging films that hold true to the spirit of circularity. During this discussion we will review some of the key technology unlocks which have contributed to the evolution of modern packaging films and explain how these have impacted the market. We will briefly touch on the challenges associated with converting traditional comingled structures to mono-material recyclable formats. With this background we can begin to look forward and build a vision for how solvent-based recycling methods will provide benefits to converters, brand owners, and consumers.

Recycling of Single-Use Multilayer Plastics for Biomanufacturing with Solvent-Targeted Recovery and Precipitation

Tushar[1], Charles Granger[1], Ali Altamimi[1], Yoel Cortes-Pena[1], Kevin Nelson[2], Xiaobo Dong[3], Karl Britt[3], Louis Barrows[3], Andrea Thurnheer[4], Styliani Avraamidou[1], Reid Van Lehn[1], George Huber[1]
[1]University of Wisconsin-Madison, [2]Amcor, [3]Cytiva, [4]Genentech

ABSTRACT

The biopharmaceutical industry increasingly relies on single-use technologies (SUTs)—primarily plastic-based components such as multilayer films, tubing, bags, bioreactors, and filters—for their advantages in flexibility, productivity, speed to market, and cost savings compared to traditional stainless-steel systems. However, SUTs are discarded after one use, creating waste management challenges. Solvent-Targeted Recovery and Precipitation (STRAP) offers a promising solution by selectively dissolving and recovering valuable polymers from mixed SUP plastic waste. In this study, we demonstrate the recycling of unused SUT plastics using STRAP, successfully extracting polyethylene (PE) and ethylene vinyl alcohol (EVOH) from bio-container films. Cast films made from STRAP-recovered PE exhibit mechanical properties and color comparable to those made from virgin low-density polyethylene (LDPE), supporting their potential for reuse in film manufacturing. Life cycle analysis reveals that STRAP reduces fossil fuel consumption and greenhouse gas emissions by 50% compared to virgin PE production, and by 80% compared to virgin EVOH production. Economic analysis shows that a STRAP facility processing a feedstock of 90% PE and 10% EVOH can be profitable at a scale as small as 3 kton/year, primarily due to the high value of EVOH. These findings highlight STRAP as a viable pathway toward circularity in the biomanufacturing industry, offering a sustainable alternative to incineration and landfilling by enabling the recovery and reuse of plastics from SUT waste.

Delamination Recycling of Multilayer Plastic Films: Solvent-assisted Separation and Recovery of Intact Solid Polyolefins

Paschalis Alexandridis, Jacob S. Licht, Marina Tsianou
University at Buffalo, The State University of New York

ABSTRACT

Films constitute about 40% of all plastic packaging, but cannot currently be handled by mechanical recycling. Polyolefin-rich films are suitable feedstock for pyrolysis, however pyrolysis breaks down the polymer chains to produce hydrocarbons that are typically used as fuel. Plastics recycling research in our group utilizes selective interactions with solvents to separate and recover individual polymers. Because the polymer chains do not break and retain their embodied energy, this is a promising, low-energy, low-greenhouse gas (GHG) plastics recycling methodology. This work advances delamination as a recycling process to separate and sequester valuable polymers from multilayer multimaterial films, facilitating the incorporation of these polymers into the circular economy. We effect delamination in a physical process that preserves targeted polymers as solid film, hence retaining their embodied energy. This work documents three different pathways of inducing delamination of multilayer films, with appropriate solvents disrupting adhesion between adjacent layers or dissolving a minor component of the film in less than an hour and at temperatures below 90 °C, and where all initial polyethylene is maintained in its solid form throughout the process and is recovered at high purity. Delamination recycling can contribute to the sustainable use of multilayer films as they continue to protect our food and medicine.

A Process-Modeling Platform for STRAP: TEA, LCA, and System Integration

Styliana Avraamidou
University of Wisconsin-Madison

ABSTRACT

Over several years, our STRAP team has developed and continuously refined a detailed process model for the STRAP technology, supporting a wide range of TEA and LCA studies. As the model has matured, it has evolved into a versatile platform for broader process systems engineering analyses. In this talk, we highlight key capabilities enabled by this platform and its integration with process systems engineering tools. First, we present an optimization framework that identifies STRAP plant designs balancing capital cost, ROI, and breakeven performance while accounting for variability in feedstock availability and composition, capabilities directly relevant to potential investors. We then show how the model supports integrated assessments of recycling pathways for complex waste streams, revealing how STRAP interacts with complementary recycling technologies. Finally, we illustrate how the model scales to national-level analyses, where STRAP functions as a core technology within infrastructure planning for post-consumer waste. Together, these capabilities demonstrate how the STRAP process model can inform decisions from plant design to system integration and long-term circularity planning.

Systems Engineering Approaches for Sustainable Plastic Management

Aurora del Carmen Munguía-López
University at Buffalo, The State University of New York

ABSTRACT

The current high plastic waste generation and low recycling rates represent a challenging problem. One of the main obstacles hindering plastic recycling is that several common plastic materials (e.g., multicomponent plastics) cannot be treated via mechanical recycling. Such materials are widely used in packaging applications (e.g., food and healthcare) due to their unique properties; however, these plastics often leave use the same year they are produced. Recently, novel technologies have emerged as promising alternatives to upcycle complex plastic waste. It is essential to evaluate the benefits and impacts of these systems to ensure that they enable economic and social development within environmental limits. Furthermore, exploring their integration into the current plastic supply chain and waste management infrastructure is needed to facilitate their deployment. In this talk, I will present how systems engineering tools can help identify sustainable plastic management strategies by integrating molecular simulations, process modeling, life cycle assessment, and techno-economic analysis. I will also discuss how our findings help guide more sustainable process and product designs. These insights can help create new infrastructure (or improve existing infrastructure) and policies to increase recycling rates and enable more circular economies. Finally, I will highlight open challenges and opportunities for future work.

AI Agent-Enabled Digital Twin for STRAP Process Control

Vinh Nguyen
Michigan Technological University

ABSTRACT

This presentation will discuss current progress on an AI agent-enabled digital twin for process and maintenance optimization of the STRAP system. Currently, AI agent-enabled interfacing with digital twins is limited with prior research treating digital twins more as static read-only databases for AI agents rather than in-process read-write systems. The reason for this limitation is that in-process interaction with AI agents is significantly more prone to hallucination. This work aims to develop an AI agent-enabled digital twin for sub-second agent responses towards optimizing the complex yet promising plastic manufacturing process conducted by STRAP. In pursuit of this larger goal, this talk will discuss efforts to create a digital twin and conduct AI-based control for the feedstock introduction component of the STRAP process. The talk will conclude with discussion of challenges and future work towards the progression of a fully-realized AI agent-enabled digital twin system throughout the entire STRAP system.

Review of Solvent-Based Technologies and Current State of the Field

Elizaveta Radkevich
University of Wisconsin-Madison

ABSTRACT

Solvent-based recycling technologies are receiving increased interest due to the ability to produce high-quality resins through the removal of intentionally and non-intentionally added substances. Several approaches show competitive techno-economic and favorable life cycle analyses compared to conventional manufacturing of virgin resins and plastic products. These technologies differ in terms of process operating steps, process conditions, and level of technological maturity. This review encompasses technologies across a broad spectrum of development stages, ranging from laboratory-scale research to commercial-scale operations. Several polymers, including polyethylene (PE), polypropylene (PP), polyvinyl chloride (PVC), polyethylene terephthalate (PET), polystyrene (PS), have been successfully recycled. Several challenges still persist in scaling up operations including transitioning from batch to continuous processing, presence of an established supply chain for recycling feedstock, and ability to consistently produce a high-quality resin at competitive prices.

Automotive Industry Needs for Transition to a More Circular Economy

Ellen Lee
Ford

ABSTRACT

Plastics and composites are used extensively throughout modern passenger vehicles to enable unique features and capabilities, accounting for approximately 10-15% of their mass but up to 50% of their volume. At the same time, upcoming regulatory actions and rising customer demand are driving automotive OEMs to increase use of sustainable content and reduce product carbon footprint for the manufacture of these plastic components. This discussion highlights the challenges for recovering and valorizing carbon from plastic waste streams including end-of-life vehicles, and the need for new and emerging technologies to overcome such barriers towards establishing a more circular lifecycle.

Dissolution-Precipitation Separation of Polyolefins for Plastics Recycling Applications

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ABSTRACT

Plastics recycling research in our group utilizes physical, solvent-based processes that do not break down the polymer chains. This supports plastic-to-plastic recycling, as the recovered polymer is essentially the same as the starting material. Further, keeping the polymer chains intact maintains their embodied energy and emits relatively little GHG. Our focus here is on polyolefins which constitute the majority of plastics produced and discarded. Our aim is to separate individual polyolefins such as HDPE, LDPE and PP from their mixtures or blends using selective dissolution of the target polyolefin, followed by its recovery via precipitation. In this context, we need to know the thermodynamics, e.g. temperature-dependent solubility, and also the kinetics of polyolefin dissolution. This presentation first addresses the mechanism of semicrystalline polyolefin dissolution as revealed through joint in-situ infrared spectroscopy experiments and diffusion kinetics modeling. The presentation then highlights the dissolution-precipitation separation and recovery of polyolefins utilizing switchable hydrophilicity solvents (SHS) that can cycle between a form that dissolves the target polymer and a form that does not, hence facilitating closed-loop solvent cycling while eliminating the cost- and energy-intensive use of antisolvents. The insights obtained from these studies facilitate the design of solvent systems and processing conditions for the molecular recycling of polyolefins via dissolution-precipitation.

Polyolefin Recovery from Municipal Solid Waste by Solvent Extraction

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ABSTRACT

Municipal solid waste (MSW) contains significant amounts of polyethylene (PE) and polypropylene (PP) that are currently underutilized, representing a lost resource. This study investigated the recovery of PE and PP from MSW using solvent extraction methods. Plastics were extracted from MSW sourced from Utah (UT) and Michigan (MI) using mixed-xylene and toluene as solvents via a modified Soxhlet extraction method. The extraction process was optimized, and the crude plastic extracts were characterized for chloride content, mechanical strength, thermal stability, and rheological properties. Optimization of the extraction process afforded crude plastic yields of approximately 16 ±2% for both MI and UT samples with toluene, while higher yields were obtained with xylene (32 ±3% for MI and 26 ±3% for UT). The crude plastic was mainly comprised of PE and some PP as determined by FTIR and DSC. Chloride content analysis of the crude plastic revealed PVC contamination of 0.49-1.2%. Solvent recovery exceeded 90%, indicating potential for scalable implementation. The extracted crude contained plasticizers and fatty acids, which had a detrimental effect on tensile properties. An acetone extraction to remove plasticizers improved the plastic tensile strength to 11 MPa, comparable to virgin LDPE. Removal of plasticizers is key to maximize plastic utilization. The crude extracted plastic could be used in wood-plastic composite applications.

Integrated Characterization of Solvent-Recovered Polymer Streams from STRAP Processing

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ABSTRACT

Solvent-based recycling technologies have emerged as promising approaches for recovering high-value polymer materials from complex plastic waste streams. Among these, solvent-targeted recovery and precipitation (STRAP) processes provide an effective pathway for selective polymer separation while preserving material properties. However, the purity, residual additives, and thermal behavior of recovered polymer streams remain critical challenges that directly influence downstream processing and reuse. In this work, an integrated characterization framework was developed to evaluate solvent-recovered polypropylene-rich streams obtained through STRAP processing. Activated carbon-assisted xylene filtration was investigated as a purification strategy for pigment removal from polymer-containing solvent systems. UV–Vis spectroscopy revealed rapid decreases in visible absorbance associated with green pigment species, with substantial color reduction occurring within the first 15–75 minutes of filtration. Additional spectral features in the ultraviolet region suggested complex interactions among residual pigments, dissolved polymer species, and solvent behavior. Thermal characterization using combined TGA/DSC analysis demonstrated melting transitions consistent with polypropylene while also enabling evaluation of potential nylon contamination and variations in polymer crystallinity. Complementary SEM/EDS analyses were further employed to examine residual inorganic species, elemental distributions, and particulate contaminants within recovered materials. The results demonstrate that combining optical, thermal, and elemental characterization techniques provides valuable insight into purification efficiency, residual contamination, and material quality in solvent-recovered polymer systems. These findings contribute to the development of more robust and scalable solvent-based recycling technologies for sustainable polymer recovery and circular plastics manufacturing.

On-Line, Real-Time, Mid-IR Spectroscopy for Plastic Identification on Industrial Conveyor Belts

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ABSTRACT

Materials recovery facilities (MRFs) commonly use near-infrared (NIR) spectroscopy for on-line plastic identification and automated sorting. However, NIR has important limitations in identifying dark and carbon-black plastics and distinguishing chemically similar polymers. Mid-infrared (MIR) spectroscopy probes fundamental molecular vibrations and provides richer chemical information that can address these limitations. We developed an on-line, real-time MIR classification system for post-consumer plastics and evaluated it under continuous conveyor motion and contamination conditions representative of industrial sorting environments. A physics-informed learning framework was used to improve robustness to conveyor-induced disturbances, including spectral shifts, noise, intensity variation, motion blur, and vibration. The resulting system achieved 94.3% accuracy on contaminated moving conveyor samples, 98.7% accuracy on clean samples, and 96% accuracy for carbon-black plastics. The real-time prototype sustained approximately 1,250 spectra/s with 99.73% uptime during an 8-hour continuous test. We will discuss the applicability of MIR spectroscopy for plastic sorting, current limitations, and the steps required toward full-scale industrial deployment.

Reclaiming Polyethylene from Multilayer Plastic Packaging for Property Characterization

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ABSTRACT

Multilayer plastic structures have been widely used in the food packaging industry for their superior performance in preventing spoilage and extending the shelf life of processed food products. The increasing use of multilayer plastic structures has also raised environmental concerns due to challenges in recycling, given the complex multilayer structure and the various polymers with different thermal behaviors. The most common example of a multilayer plastic structure in food packaging comprises five or more layers, with polyolefin layers sandwiched between a middle layer of an oxygen barrier polymer, such as poly(ethylene-co-vinyl alcohol) (EVOH), and an adhesive resin layer that bonds the polyolefin and EVOH layers. The objective of this research was to develop a process to dissolve the middle oxygen barrier layer, thereby separating EVOH and polyethylene from the multilayer structure, enabling the reclamation of polyolefins in the solid phase and EVOH in solution. Formic acid was used as a solvent to dissolve EVOH, and the dissolution process for EVOH was optimized. The research indicated that formic acid is a good candidate for separating multilayer plastic structures for recycling. The effect of the selective dissolution process on the properties of the reclaimed polyethylene was characterized to evaluate the reusability. No significant change in polyolefin properties was observed.

Getters: A Novel Approach to Recycle High-Quality Polypropylene from Single-Use Technology (SUT) Waste Streams

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ABSTRACT

The biopharmaceutical industry is transitioning from traditional stainless-steel systems to single-use technologies (SUTs), generating substantial volumes of mixed plastic waste that are typically landfilled or incinerated. These waste streams contain high-quality polymers, creating opportunities for circular economy-driven recycling approaches. Solvent-Targeted Recovery and Precipitation (STRAP) is an emerging recycling technology that selectively dissolves target polymers in suitable solvents; however, ultrafine additives commonly incorporated into plastics remain dispersed in solution and are difficult to remove using conventional filtration methods. To overcome this challenge, a sacrificial polymer ("getter") is introduced to bind the additive particles, promoting their agglomeration into larger clusters that can be separated through precipitation and filtration. In this study, connectors and clamps from a 50 L single-use bioreactor bag, representing approximately 31 wt% of the bioreactor bag, were investigated. These components are composed of polypropylene (PP) containing titanium dioxide (TiO_2) additives. The work focuses on identifying suitable getter materials for effective TiO_2 removal and PP recovery by characterizing the thermal and dissolution behavior of both feedstock-derived and virgin PP resins. This novel methodology will enable scalable polymer reclamation strategies that advance sustainability and circularity within the bioprocessing industry.