RE 4th IC
TA 2026

The 4th Rubber - Elastomer Technology Association of Thailand International Conference

"Eco-friendly and Sustainable Solutions"

28-29 MAY 2026
Bangkok, THAILAND

e-Abstract

The Rubber-Elastomer Technology Association of Thailand (RETA)
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RETA International Conference 2026

"Eco-friendly and Sustainable Solutions"

Pathumwan Princess Hotel (M Floor)

May 28–29, 2026

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About the Conference

The Rubber-Elastomer Technology Association of Thailand (RETA) will hold the 4th RETA International Conference (RETA-IC 2026) between May 28- 29, 2026 at the Pathumwan Princess Hotel, Bangkok. This conference aims at identifying links and creating relationships between researchers from academia and industry to create advances in the science and technology of rubber and elastomers and build cooperation.

The association recognizes the importance of developing knowledge and creating innovations in rubber and elastomer technology including building a networks between the academic and industrial. It provides a platform to disseminate the scientific knowledge to the society and enable them to use these research findings in order to develop new technology.

The association will invite world-renowned scientists and young scientists with outstanding achievements to be the leading speakers to serve as examples and motivators for the development of research in the country, as well as to create cooperation and the transfer of new technologies to researchers from both academia and industry in the country continuously.

The RETA-IC 2026 Conference has two important parts; the first part is the presentation of research by guest scientists, lectures by researchers from academia and industry including a presentation of researchers by poster presentation. The second part is the exhibitions featured both engineering and technology from rubber and elastomer industries which is a supporting part of the seminar.

Message from the President

It is my great pleasure to welcome you to the Rubber and Elastomer Association International Conference 2026 (RETA-IC 2026). RETA-IC brings together local and global communities in rubber, elastomers, and green materials. RETA currently comprises approximately 200 members from both the private and public sectors, including university professors, researchers, investors, and students.

RETA-IC 2026 is held under the theme "Eco-friendly and Sustainable Solutions," emphasizing the advancement of rubber and elastomer materials toward environmentally responsible and durable applications. The conference features three main sessions: Trends in Natural Rubber and Their Social Impacts (NR), Vital Roles of Synthetic Rubber and Elastomers (SR), and Unlocking the Potential of Green Materials (GM), along with two plenary lectures and more than ten keynote and invited speakers.

This year, RETA-IC 2026 hosts two joint symposiums. The first, under the JSPS Core-to-Core Program led by Prof. Hiroshi Uyama (Osaka University), focuses on plastic and bio-based material circulation, including recycling, upcycling, and biodegradation, with participants from Thailand, Malaysia, and Vietnam. The second, under the SATREPS Program led by Assoc. Prof. Shinji Kanehashi (Tokyo University of Agriculture and Technology), highlights rubber seed utilization for biochemicals, biomass plastics, bioenergy, greenhouse gas reduction, and life cycle analysis, involving institutions from Japan and Thailand.

RETA-IC 2026 is expected to welcome more than 120 participants, fostering collaboration, knowledge exchange, and innovation. We are confident that this conference will serve as a valuable platform to advance sustainable solutions in rubber and elastomer science and technology.

On behalf of RETA, I sincerely thank all speakers, participants, organizers, and sponsors for their contributions, and I wish you a fruitful and inspiring conference.

Prof. Suwabun Chirachanchai, Ph.D.
President, Rubber and Elastomer Association of Thailand (RETA)

Sessions

NR: Trends in Natural Rubber and their Social Impacts

- Progress in rubber analysis and testing
- Rubber Technology and Engineering Materials
- Environmentally Friendly Rubber Materials
- Rubber Materials and Composite
- End of Life and Circular Economy of Rubber and Polymeric Product
- Latex and Rubber Industrial Products, Materials, and Components

SR: Vital Roles of Synthetic Rubber and Elastomers

- Bio-based elastomers
- Synthetic rubber materials, components, and additives
- Smart, intelligent synthetic rubbers
- Progress in rubber analysis and testing
- Recyclable elastomers (TPEs, TPRs)
- Soft Matters

GM: Unlock Potential of Green Materials

- Challenges and Opportunities in Bio-plastic
- Plastic Recycling Innovation
- Bio-based Polymers for Advanced Materials
- Environmentally friendly materials, zero waste and recycling

CC: JSPS Core-to-Core Program

HT: Hub of Talents in Natural Rubber, NRCT

ST: SATREPS

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Speaker Session ST : SATREPS

Poster Session NR : Trends in Natural Rubber and their Social Impacts

Poster Session SR : Vital Roles of Synthetic Rubber and Elastomers

Poster Session GM : Unlock Potential of Green Materials

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Poster Session CC : JSPS Core-to-Core Program

Poster Session CC : JSPS Core-to-Core Program

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Plenary Speakers

Material Design and Degradation Engineering for Plastics and Textile Recycling

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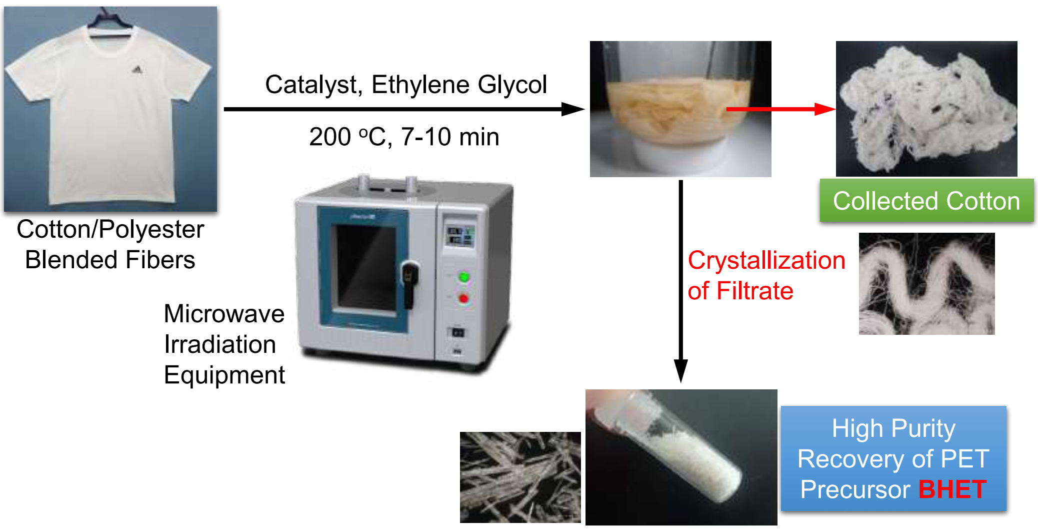
Abstract (Times New Roman, 12 pt, justify, not exceed 250 words, justify, graphical abstract can be included but overall abstract pages should not be more than 2 pages)

In the transition toward a decarbonized society, reducing CO_2 emissions and plastic waste is a critical challenge. Plastics and synthetic textiles, especially cotton/polyester blends, are difficult to recycle because of their heterogeneous composition. While mechanical recycling is widely used, chemical recycling offers a promising route for recovering high-purity monomers from complex materials. We have developed a selective chemical recycling process for cotton/polyester blended fibers using microwave irradiation in the presence of a specific catalyst and ethylene glycol (Scheme 1). Within a few minutes, the polyester component is efficiently depolymerized into bis(hydroxyethyl) terephthalate (BHET), while the cotton fibers remain mechanically intact. Ethylene glycol serves as both solvent and reactant, and the selective catalyst enables polyester depolymerization under mild conditions without damaging cellulose. The recovered BHET is purified by simple crystallization with yields of approximately 70%, and cotton fibers are obtained almost quantitatively. This approach is expected to provide a practical pathway for recycling blended textiles and could be extended to other polymer blends, contributing to a circular economy for plastics and fibers. The recovered monomer can be directly reused for polyester resynthesis, enabling closed-loop material circulation. The concept also offers insights into material design for recyclability at the molecular level.

Scheme I



Reinventing Natural Rubber: Engineering Allergy-Free Latex for Global Health, Industry, and Sustainability

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Natural rubber (NR) is a critical biomaterial for healthcare and industrial applications, valued for its superior elasticity, strength, and renewability. However, intrinsic allergenic proteins in natural rubber latex (NRL) remain a major concern, particularly in medical and occupational settings where type I hypersensitivity reactions can pose serious health risks. As a leading global producer, Thailand plays a key role in advancing safer and higher-value NR technologies.

This plenary presentation introduces an integrated and scalable approach to engineering allergy-free NRL through deproteinization and saponification processes, yielding highly purified latexes—deproteinized natural rubber (DPNR) and saponified natural rubber (SPNR). These materials exhibit significantly reduced extractable protein content and effective removal of major allergens (Hev b1, b3, b5, and b6.02), as confirmed by ELISA and SDS-PAGE analyses.

Importantly, allergen reduction is achieved without compromising performance. Vulcanized products derived from purified latexes demonstrate enhanced barrier properties against chemical and microbial penetration, improved elasticity and tensile strength exceeding ASTM standards, reduced discoloration, and superior comfort. These results challenge the traditional trade-off between safety and functionality in latex products.

From a global health perspective, while latex allergy prevalence has declined with the adoption of low-protein, powder-free gloves, economic constraints limit the widespread use of synthetic alternatives in many regions. The technologies presented here offer a practical and cost-effective pathway to reduce allergenic risks while preserving the intrinsic advantages of NR, supporting large-scale industrial implementation.

By bridging molecular-level material design with industrial scalability, occupational health, and sustainability, this work redefines the future of natural rubber as a safe, high-performance, and environmentally responsible material platform for next-generation personal protective equipment.

Research Keyword:
Natural Rubber Latex, Allergy-Free Materials, Deproteinization, Saponification, Sustainable PPE, Latex Allergy Prevention

Speaker

Session NR

Trends in Natural Rubber and their Social Impacts

Natural Rubber and their Social Impacts

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Rubber Authority of Thailand

Abstract

The global natural rubber (NR) industry has been significantly affected by the Middle East conflict — initiated by the United States and Israel against Iran on February 2026 — which rapidly emerged as one of the most consequential geopolitical disruptions to global commodity markets in recent years. The conflict has triggered an asymmetric supply shock across energy, fertilizer, and freight markets, simultaneously reshaping the global natural rubber (NR) industry in ways that are both challenging and strategically advantageous for the NR producer. First, global NR prices have risen to their highest levels in two years, driven by surging synthetic rubber (SR) costs, maritime disruptions, and a prolonged wintering season in Southeast Asia. Second, the global NR market remains in structural deficit. Third, the elevated crude oil environment — which peaked at approximately USD 138 per barrel in April 2026 — has significantly widened the cost disadvantage of synthetic rubber relative to natural rubber, creating a commercially actionable window for exporters and policymakers.

Natural rubber benchmark prices across major exchanges accelerated sharply in early April 2026 as the conflict escalated. The price rally is rooted in a confluence of factors: the Strait of Hormuz closure raised transport risks and lifted oil costs; wintering season shortages across major Southeast Asian producing countries; extreme heat disrupting tapping schedules; and surging synthetic rubber costs that diverted demand toward NR.

Global natural rubber production at 15,322 thousand tonnes in 2026, an increase of 2.2% from an estimated 14,996 thousand tonnes in 2025. This modest growth reflects gains supported by higher grower prices, partially offset by adverse weather conditions, insufficient replanting investment, and uncertainty stemming from the Middle East conflict. Thailand remains the world's largest producer at 4,790 thousand tonnes in 2025, forecast to rise to 4,857 thousand tonnes in 2026 (+1.4%), while Indonesia continues its structural decline from 2,041 to 2,025 thousand tonnes (−0.8%). Notably, the Rest of World — led by Côte d'Ivoire — is projected to expand most rapidly at +6.5% to 3,664 thousand tonnes. Moreover, a trend primarily attributable to the wintering season across major producing countries, compounded by dry weather and abnormally high temperatures across Southeast and South Asian growing regions. (ANRPC, March 2026)

However, the Key Policy Developments of some producing countries can also affect Supply-Side that two significant policy and investment signals reinforce the longer-term supply outlook. For example, In Malaysia--the government raised rubber replanting assistance incentive income for the rubber smallholders under the Malaysia Plan — targeting 33,000 smallholders and 50,000 hectares of replanting over five years, In Indonesia, established a formal international research collaboration with Bridgestone Corporation, Yokohama City University, and Maebashi Institute of Technology on elite Hevea brasiliensis genetics (signed 7 April 2026), aimed at identifying superior rubber tree varieties with higher and more stable productivity through marker-assisted selection. (ANRPC, March 2026).

Global NR consumption is projected to grow modestly by 1.4% year-on-year in 2026, reaching an estimated 15,602 thousand tonnes, up from 15,385 thousand tonnes in 2025. China remains by far the dominant consumer at 7,008 thousand tonnes in 2025, followed by India at

1,439 thousand tonnes. Thailand and Viet Nam are projected to see domestic consumption contract slightly, at −2.8% and −5.7% respectively, reflecting inventory adjustments and geopolitical headwinds. Malaysia stands out with a projected 9.7% increase in domestic consumption. Broader international demand remains under pressure from geopolitical uncertainties and the escalation of US trade tariffs. (ANRPC, March 2026).

Key Demand Drivers for two players such as China, India which shown that China's natural rubber consumption increased from a manufacturing PMI that rose to 50.4, Chinese total automobile exports reached 2.226 million units. The sustained expansion of EV production is structurally significant for NR: EV tyres require approximately 15–20% more natural rubber per vehicle than comparable internal-combustion-engine models, owing to the additional load demands imposed by heavier battery packs. In India, the strongest-ever retail automotive month, with total vehicle sales surging to 2.69 million units, including record passenger vehicle sales and EV penetration in the three-wheeler segment — all generating incremental NR demand.

In terms of the socioeconomic consequences in the 2026, the Middle East conflict and other related factors in the world situations extend well beyond farm-gate income, affecting employment stability, household food security, educational investment and environmental stewardship across rubber-growing communities.

Regarding regional Impact across Thailand, the severity of the conflict's social and economic impact varies considerably across Thailand's rubber-growing regions, shaped by local weather conditions, farm structure, proximity to export facilities, and the availability of industrial employment alternatives. The Key risk factors will be divided into three levels: High Risk, Medium Risk and Low Risk. High Risk Level consists of the severe drought; rainfall 69% below normal in March 2026; temperatures reaching 42–43°C, the Security challenges compound conflict-driven cost increases; elevated logistics costs and the Severe heat waves; younger plantations with lower yields; limited support infrastructure. By contrast, regions in the Medium Risk category face elevated logistics costs that partially offset the gains from higher rubber prices, while Low Risk regions — notably those in close proximity to major export ports and processing facilities — are best positioned to capitalise on the current market environment.

Supply Chain in the Rubber Industry - An Overview

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Abstract

An overview look at the supply chain to the rubber industry coming from petrochemicals. Brief outlook on possible impact from Iran War and potential effects on rubber industry supply chain for Thailand and Malaysia.

Total Value Chain Development for NR Sustainability

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Abstract

Natural rubber (NR) is no longer just a commodity product. It is becoming a strategic sustainable material in the global market. Today, increasing pressure from regulations such as the EU Deforestation Regulation (EUDR) is driving the industry to transform toward greater transparency, traceability, and responsible sourcing. Our company focuses on developing a sustainable total value chain for NR, covering the entire system from upstream farmer engagement, to midstream processing, and downstream product applications. At the upstream level, we emphasize compliant sourcing and geolocation-based traceability, while also supporting farmers through the implementation of agricultural standards such as Good Agricultural Practices (GAP) and Good Manufacturing Practices (GMP). These standards help ensure safe and standardized farming practices, strengthen quality control from the plantation level, and promote sustainable agriculture. As a result, farmers are able to improve their income through higher-quality production.

In the midstream, we focus on improving processing efficiency, reducing emissions, and optimizing resource use, particularly in block rubber production such as STR20 and STR5L. At the downstream level, NR is increasingly applied in high-value and sustainable applications, including footwear, sporting goods, automotive components, and consumer products. In particular, this work explores the potential of NR to partially replace synthetic rubber, contributing to lower carbon footprint products and supporting the transition toward bio-based materials. At the same time, value-added strategies including certification, cleaner production technologies, and digital traceability platforms are enabling NR producers to move beyond price-based competition toward premium and sustainable markets.

Ultimately, integrating sustainability across the entire value chain not only helps reduce regulatory risks, but also creates long-term value for all stakeholders. This positions natural rubber as a key material in the transition toward a circular and low-carbon economy.

Future Leaders of Rubber: Are We Preparing Them?

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Abstract:

The rubber and elastomer industry is undergoing a rapid transformation driven by sustainability demands, digital technologies, and increasing global competition. While organizations continue to invest in advanced materials, automation, and processes, a critical question remains: are we equally investing in preparing the people who will lead this transformation? This presentation explores the growing leadership gap across the industry, highlighting challenges such as limited leadership development, family business succession issues, and the disconnect between academic education and real industry needs.

It emphasizes that technical knowledge alone is no longer sufficient. Future leaders must combine technical expertise with business understanding, sustainability awareness, digital readiness, and strong communication skills. The talk also calls for a collaborative approach involving industry, academia, alumni, and faculty to strengthen infrastructure, improve practical learning, and build leadership capability at all levels. Ultimately, it presents a thought-provoking perspective that the future of the rubber industry will not be shaped by technology alone—but by the leaders we prepare today.

Biography

Peram Prasada Rao is the Founder and CEO of TechnoBiz, a global platform focused on knowledge sharing and business growth in the rubber, polymer, and polyurethane industries. With over 28 years of international experience, he is recognized as an industry strategist and ecosystem builder. A Chemical Engineer with a Master's in Environmental Engineering, he actively supports companies in marketing, branding, and capability development. Under his leadership, TechnoBiz has completed a 20-year journey, emerging as a positive catalyst for workforce development and business growth across the rubber and polymer industries.

He has established global platforms such as Rubber Week, PU Week, PolyWorld, Global Rubber, Latex & Tyre Expo (GRTE) and Middle East Rubber & Tyre Expo (MRTE) connecting industry professionals worldwide. He also leads industry publications including Rubber Review, Plastics Review, and PU Review, and has enabled access to hundreds of specialized reference books through the TechnoBiz Store to support continuous learning.

His initiative on Executive Diploma Programs, customized based on participants' background and business profile, is a unique and globally well-received approach to skill development in the industry. TechnoBiz continues to evolve by staying relevant to current and future needs, and every rubber professional and business can benefit from connecting with the platform. For latest updates, please visit www.technobiz.org

Natural Rubber Serum Biorefinery: Transforming an Industrial Waste Stream into High-Value Bioactive Compounds

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Abstract

Natural rubber serum, accounting for 60–70% of natural latex, has long been treated as industrial waste despite its richness in proteins, enzymes, carbohydrates, and other non-rubber biomolecules. In Thailand, more than one billion liters are discarded annually, creating environmental and economic burdens. Here, we present a Bio-Circular-Green (BCG) biorefinery platform that redefines natural rubber serum as a scalable feedstock for producing bioactive compounds (Fig. 1).

Using serum-derived non-rubber components as biocatalytic resources, we developed industrially translatable processes for producing β-glucan oligosaccharides (BGOs; hydrolyzed yeast β-glucan, HBGs) [1,2] and achieved industrial-scale extraction of Hevea Latex Polysaccharides (HeLP) [3,4]. The process also yields co-products, including quebrachitol and protein fractions, the latter showing promise as plant-based protein ingredients.

HeLP and BGOs are under evaluation through Thailand FDA's Novel Food pathway. HeLP has recently been certified as safe for human consumption, whereas BGOs are being assessed in clinical studies. Functional studies indicate that HeLP, BGOs, and quebrachitol exhibit anti-wrinkle, wound-healing, anti-inflammatory, immunomodulatory, anticancer potential, gastroprotective, anti-diabetic, and prebiotic activities, supporting applications in cosmeceuticals, functional foods, dietary supplements, future foods, and pharmaceutical-related products. Several of these bioactives have already been incorporated into commercial cosmeceutical products.

To enable commercialization, CERB is partnering with Innozus Co., Ltd. to establish the first GMP-certified natural rubber serum biorefinery at the Southern Industrial Estate, scheduled to begin operation in June 2026. This initiative establishes a new paradigm for valorizing rubber-processing by-products while reducing waste, strengthening Thailand's biorefinery sector, and advancing the BCG economy and the United Nations Sustainable Development Goals.

Fig. 1. New rubber value chain

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Natural rubber for triboelectric nanogenerator as new energy harvesting technology: synergistic effect of dielectric modulation and photocharge generation for output performance enhancement

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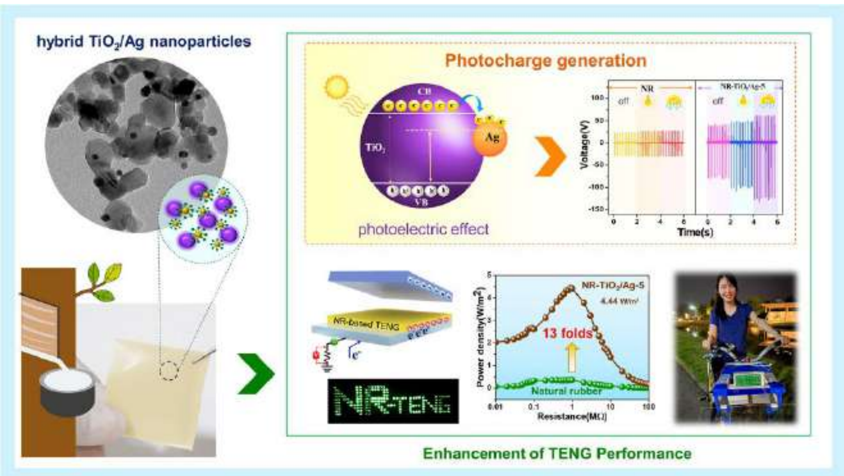
Triboelectric nanogenerators (TENGs) have attracted significant attention as an emerging technology for harvesting mechanical energy from the ambient environment and converting it into electricity through the combined effects of contact electrification and electrostatic induction. In this work, a natural rubber (NR)-based TENG with enhanced energy conversion performance was successfully developed. TiO_2/Ag hybrid nanoparticles were synthesized and incorporated into the NR matrix to improve the electrical output performance of the TENG. The developed approach facilitated the uniform dispersion of TiO_2/Ag nanoparticles within the NR polymer matrix, resulting in a significant improvement in the energy harvesting efficiency of the device. The NR–TiO_2/Ag TENG achieved a maximum power density of 4.44 W/m^2, which was approximately 13 times higher than that of the pristine NR-based TENG. The remarkable enhancement was attributed to the synergistic effects of dielectric interfacial polarization induced by Ag nanoparticles and photoinduced charge generation arising from the photoelectric properties of TiO_2, which collectively contributed to the increased triboelectric charge density. This work presents an innovative strategy for advanced TENG material design by integrating both mechanical and light energy harvesting into a single platform, thereby offering strong potential for future sustainable energy technologies and self-powered electronic devices. Moreover, this approach adds value to natural resources, aligns with the Bio-Circular-Green (BCG) economy model, and demonstrates significant potential to support the transition toward sustainable and environmentally friendly energy technologies.



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Shaping the Future of Rubber Products: An overview of Advanced Materials and Processing Technologies

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Abstract

The global rubber industry is undergoing the most significant transformation since Charles Goodyear discovered vulcanization in 1839. Driven by demands for sustainability, extreme performance, traditional natural and synthetic rubbers are being re-engineered in response to rising performance expectation, sustainability compliance and increasingly complex application requirement. Further, conventional manufacturing approaches are no longer sufficient to meet future market demands. To remain competitive and relevant, the industry must embrace advanced materials and next generation processing technologies that tightly integrate product innovation with manufacturing excellence.

This presentation provides an overview how advances in rubber compounding, processing, moulding, and curing technologies are reshaping the future of rubber products since the ‘Liquid Phase Compounding’ process developed/commercialized by Bernard Wilkinson in 1923. The Malaysian rubber industry has been striving to evolve from a labour intensive, cost focused function to a strategic enabler of innovation, quality, and differentiation. Compounding technologies, including high performance bio-based sustainable elastomers, nanocomposite and hybrid fillers, reclaimed rubber devulcanization, etc coupled with improved mixing systems resulting in enhanced durability, consistency, safety and reliability to meet demanding applications. Precision moulding and advanced curing technologies that allow manufacturers to achieve tighter tolerances, improved the importance of integrating research and development with manufacturing capability, ensuring that new materials and product designs are scalable, robust, and commercially viable.

Through an industry leadership perspective, we highlight the role of collaboration, capability building, and ecosystem alignment—where industry associations such as MRPMA, MARGMA in collaboration with MRB, MRC, local universities, education/training institutions e.g. PRIM all play a key role in accelerating technology adoption and strengthening Malaysia’s rubber manufacturing competitiveness.

Metal–Ligand Coordination for Enhancing Cure Behavior, Mechanical Performance, and Network Reversibility in Epoxidized Natural Rubber

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Abstract

Epoxidized natural rubber (ENR) offers a sustainable approach for developing advanced elastomeric materials through reactive epoxide groups capable of forming coordination crosslinks. In this study, ENR with 25 mol% epoxidation (E25) was compounded with magnesium chloride ($MgCl_2$), stannous chloride ($SnCl_2$), and ferric chloride ($FeCl_3$) at concentrations of 5–7 mmol to investigate their effects on chemical crosslinking propagation, tensile properties, and bonding reversibility. The crosslink network characteristics revealed clear differences among the metal ions. $FeCl_3$ exhibited the fastest crosslinking rate and the highest maximum torque, indicating rapid and extensive E25 network formation, whereas $MgCl_2$ displayed limited reactivity due to its lower charge density and weaker coordination ability. The formation of metal–oxygen coordination bonds was clarified through the infrared spectroscopy among the absorption peak vibration of 451–484 cm^{-1}, in particular the cases of using Fe-containing composites. In addition, the effective crosslink density, determined using the Flory–Rehner equation and supported by temperature scanning stress relaxation (TSSR), showed that the ferric (III) ions (Fe^{3+}) generated the most densely crosslinked and rigid networks, while magnesium (II) ions (Mg^{2+}) had demonstrated the minimal influence. Tensile strength increased significantly from 0.09 MPa for pure E25 to 2.45 MPa for the E25/$FeCl_3$, while $SnCl_2$ provided moderate reinforcement. For the bond reversible, the composites were cut and conditioned at 120°C before measuring the tensile properties. It was found that the coordination bonds can reversibly dissociate and refabricate, allowing recovery of mechanical properties, particularly in $FeCl_3$. This evident was supported by the thermal stability of the composites and observed that the E25 composites with Fe–O bond dissociation had occurred at 120–140°C. These findings suggest that $FeCl_3$ induced coordination crosslinking is a promising strategy for developing ENR based material with enhanced mechanical strength and thermally reversible networks.

Keywords: Epoxidized natural rubber, Metal–oxygen interactions, Reversible network, Coordination crosslinking, Crosslinking density

Sustainable Natural Rubber Composites Reinforced with Eggshell-Derived $CaCO_3$/$BaCO_3$ Hybrid Fillers: Mechanical Performance and Radiation Shielding

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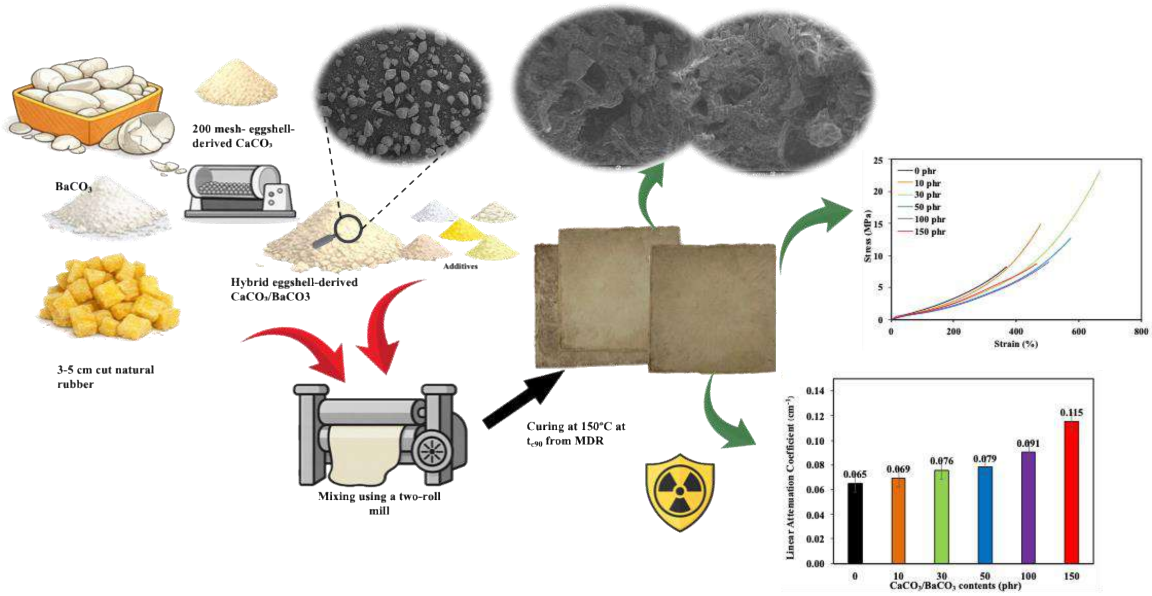
Abstract

This study investigates the use of hybrid fillers based on eggshell-derived calcium carbonate ($CaCO_3$) and barium carbonate ($BaCO_3$) for improving the mechanical and X-ray shielding properties of natural rubber (NR) composites. This work proposes a sustainable hybrid filler approach that combines waste-derived eggshell $CaCO_3$ with high atomic number $BaCO_3$ to simultaneously enhance mechanical performance and X-ray attenuation efficiency in NR composites. The hybrid filler was prepared by ball milling $CaCO_3$ (200 mesh) and $BaCO_3$ at a fixed weight ratio of 50:50, while SEM/EDX analysis was used to examine the morphology and elemental distribution of the hybrid filler prior to incorporation into the NR matrix at loadings ranging from 0 to 150 phr. At low to moderate filler contents, the NR composites exhibited improved mechanical performance. Tensile strength increased and reached a maximum value of 23.3 MPa at 30 phr, while tear strength showed the highest value of 27.9 N/mm at 10 phr. At higher filler loadings, both properties gradually decreased, which was attributed to filler agglomeration and the formation of stress concentration regions within the NR matrix, as observed from SEM analysis. In contrast, hardness continuously increased from 28.5 to 58.4 Shore A with increasing filler content, indicating reduced mobility of the polymer chains due to the reinforcing effect of the hybrid filler. The incorporation of the hybrid filler also significantly enhanced X-ray attenuation performance. The linear attenuation coefficient (μ) increased from 0.13 cm^{-1} for neat NR to 1.3 cm^{-1} at 150 phr, mainly due to the presence of high atomic number $BaCO_3$, which improves photon interaction within the composite. In addition, neutron attenuation performance improved with increasing filler loading. The μ values for fast neutrons increased from 0.065 to 0.115 cm^{-1}, while thermal neutron attenuation reached a maximum value of 1.31 cm^{-1} at 100 phr. Overall, filler contents in the range of 10–30 phr provided a more balanced combination of mechanical properties and structural integrity, whereas higher filler loadings were more effective for X-ray shielding applications. The developed composites show potential for use in flexible X-ray shielding sheets, medical protective materials, and radiation-related industrial applications.

Keywords: Natural rubber composites, Egg shell–derived calcium carbonate, Barium carbonate, Hybrid filler, Lead-free radiation shielding

Graphical abstract



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Energy-Efficient Production of Natural Rubber Block Using Rotary Disc Granulator (RDG) with Improved STR Quality Characteristics

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Abstract

Natural rubber (NR) has gained renewed attention amid growing global concerns regarding environmental and climate change. NR exhibits a significantly lower carbon footprint NR (at approx. 283 g CO_2e/kg) compared to synthetic rubbers. However, current production processes for NR block rubber from cup lumps involve multiple mechanical steps including slab cutter, wet pre-beaker, creper and shredder to remove impurities prior to drying and block formation. These processes consume substantial energy and water, leading to increased carbon emissions. [1]

This study presents a novel approach for modern natural rubber block production using a Rotary Disc Granulator (RDG) [2] as an alternative to conventional processing. The objective is to evaluate the effectiveness of RDG technology in reducing energy consumption while maintaining rubber quality in accordance with Standard Thai Rubber (STR) specifications. Natural rubber blocks were produced using both conventional and modern processes. The specific energy consumption (SEC) [3] of each process was evaluated and compared using Tecnomatix Plant Simulation. Additionally, key material properties were characterized, including dirt content, ash content, nitrogen content, volatile matter, initial plasticity (P_0), plasticity retention index (PRI), and Mooney viscosity. The results demonstrate that the modern process reduced SEC by approximately 30% compared to the conventional method. Improved cleanliness was observed, with dirt content decreasing from 0.0327 to 0.0235 wt.% and lower ash content. Other properties remained within STR requirements. Notably, PRI increased from 79.8 to 85.7, indicating enhanced thermal-oxidative stability. In conclusion, RDG technology offers a promising, energy-efficient alternative for NR block production, supporting sustainable and cost-effective industrial processing.

Research Keyword:
Natural rubber processing, Energy efficiency, Specific energy consumption (SEC), Rotary Disc Granulator (RDG)

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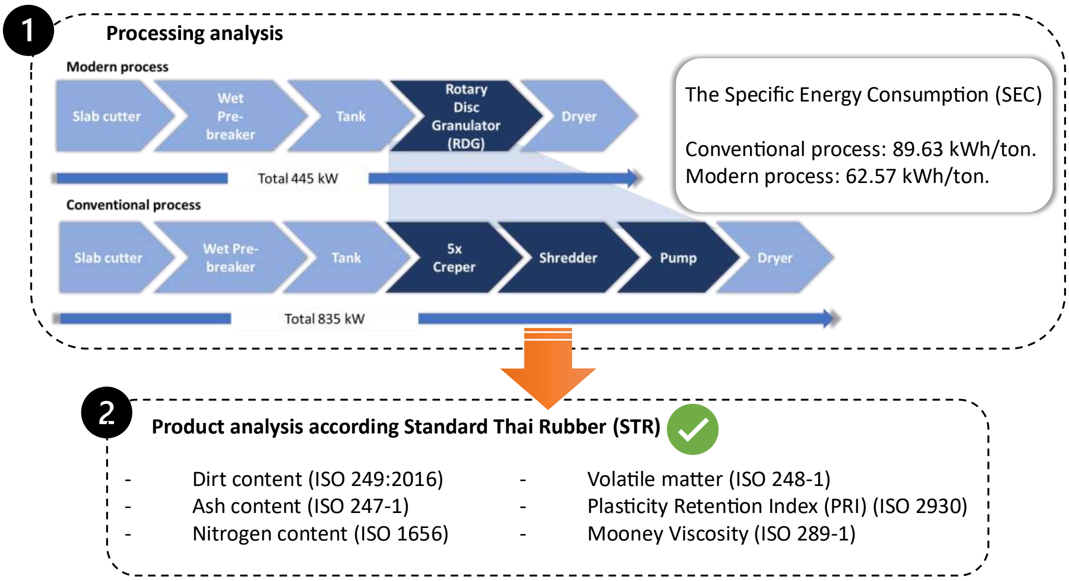
1
Processing analysis
Modern process
Slab cutter
Wet Pre-breaker
Tank
Rotary Disc Granulator (RDG)
Dryer
Total 445 kW
Conventional process
Slab cutter
Wet Pre-breaker
Tank
5x Creper
Shredder
Pump
Dryer
Total 835 kW
The Specific Energy Consumption (SEC)
Conventional process: 89.63 kWh/ton.
Modern process: 62.57 kWh/ton.
2
Product analysis according Standard Thai Rubber (STR)
- Dirt content (ISO 249:2016)
- Ash content (ISO 247-1)
- Nitrogen content (ISO 1656)
- Volatile matter (ISO 248-1)
- Plasticity Retention Index (PRI) (ISO 2930)
- Mooney Viscosity (ISO 289-1)

Effect of Encapsulated Essential Oils and $KMnO_4$-Activated White Charcoal on the Properties of Natural Rubber Sheets for Active Packaging of Climacteric Fruits

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Natural rubber (NR) absorber sheets are gaining increasing attention for active packaging applications due to their flexibility and biodegradability. However, the incorporation of functional additives to impart ethylene-absorbing and insect-repelling properties often affects the mechanical performance of the material, limiting its practical use. To date, the addition of functional fillers and bioactive compounds into rubber matrices has been considered a promising approach to develop multifunctional materials while maintaining structural integrity.

We believe that incorporating potassium permanganate–activated white charcoal (CUK) and encapsulated essential oils (EOs) into prevulcanized natural rubber latex (PNR) is an effective approach to fabricate active rubber sheets for climacteric fruit applications. In this study, three encapsulated essential oils, lemon (LEO), clove (CLEO), and eucalyptus (ETEO) were incorporated at 3 wt%. The NR rubber sheets were prepared through mixing, casting, and drying processes. The resulting NR sheets were characterized in terms of chemical structure, crosslink density, swelling behavior, water vapor permeability, mechanical properties, surface morphology, and ethylene absorption efficiency.

The results indicated that the incorporation of CUK combined with encapsulated eucalyptus or lemon essential oil slightly increased the crosslink density compared to the control. The sheet containing encapsulated lemon essential oil exhibited the highest tear strength. Notably, all essential oils showed no significant effect on modulus or elongation at break. These findings indicate that the developed NR sheets retain adequate mechanical properties and have strong potential for use as active packaging materials for climacteric fruits.

Scheme I

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Research Keywords: Natural rubber latex, Encapsulation essential oil, Potassium Permanganate ($KMnO_4$), Ethylene absorption

Promising yield and characteristics of bio-oil derived from pyrolysis of industrial natural rubber waste for liquid bio-fuel applications

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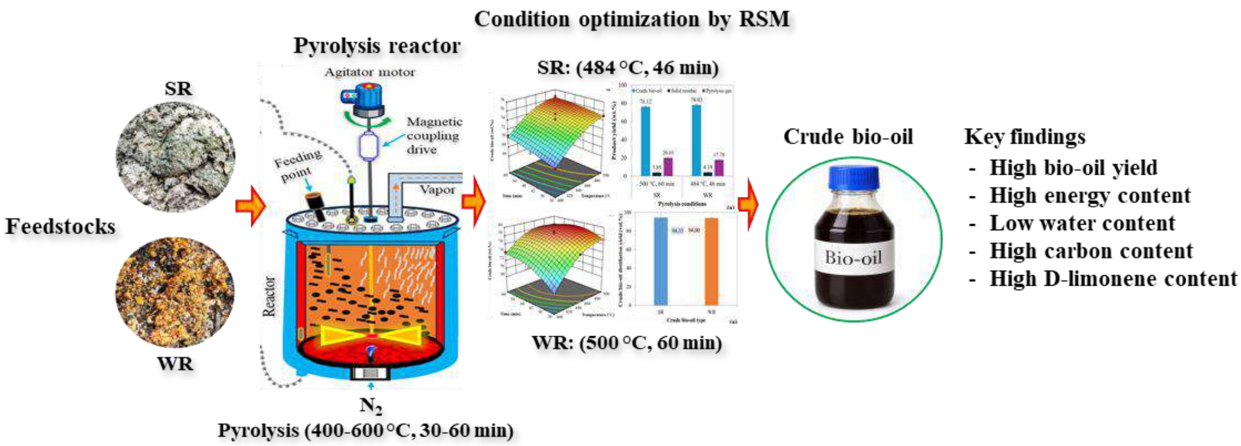
Abstract

Thailand ranks first in natural rubber (NR) production and exportation. Most of the production is concentrated in the southern region of the country. This leads to the generation of substantial industrial waste streams that require effective management to support the bio-circular-green (BCG) economy [1, 2 and 3]. Thus, this study investigates the conversion of industrial NR wastes, including skim rubber (SR) waste and waste rubber (WR) from block rubber production, into bio-oil via pyrolysis and distillation for applications as liquid biofuels. Pyrolysis experiments were conducted at 400-600 °C with residence times of 30-60 min under an inert atmosphere. Then, the yields and characteristics of crude and distilled bio-oil samples were determined and explored. The results showed that high bio-oil yields of 70-80 wt.% were achieved, attributed to the high volatile matter content (>75 wt.%) of NR wastes and favorable thermal degradation behavior. The optimal pyrolysis conditions for SR and WR predicted by RSM were 500 °C for 60 min and 484 °C for 46 min, yielding 76.27 and 79.28 wt.% bio-oil, respectively. Subsequent distillation (60-340 °C) significantly improved the bio-oil quality, producing fractions with high carbon content (84-87 wt.%) and elevated higher heating values (39-45 MJ/kg). FT-IR and GC-MS analyses confirmed that the bio-oils were dominated by aliphatic and aromatic hydrocarbons with minimal oxygenated compounds, indicating effective deoxygenation during pyrolysis. D-limonene (60-62 %) was identified as the major component in the distilled products, highlighting strong potential for selective chemical recovery. These findings demonstrate that NR waste pyrolysis and upgrading provide an efficient and scalable pathway for producing fuel-grade bio-oil.

Keywords: Biomass pyrolysis, Biofuel, Bio-oil, Natural rubber waste, Pyrolysis

Graphical abstract



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REE 4th IC
TA 2026

Speaker

Session SR

Vital Roles of Synthetic Rubber and Elastomers

Driving Global Growth in Self-Sealing Tires with Next Generation SILASTIC™ SST 8860

Tim Morley[1], Frederic Gubbels[1], Francois de Buyl[1], Thomas Davidian[1], Kevin Van Tiggelen[1]

Presented by: Kranthi Bannuru[1] (kbannuru@dow.com)

[1]*Dow*

Abstract

Over the past few years, Dow has developed the innovative SILASTIC™ Self-sealing silicone for the growing self-sealing tires market. Partnering with Bridgestone, the B-SEAL[S] sealant technology has recently been launched in a Bridgestone tire on several leading electric vehicle platforms. The Dow SILASTIC™ SST 2650 offers numerous advantages over traditional butyl-based technologies, including high sealing efficiency in various weather conditions, no need for laser pre-cleaning, and room temperature coating application. This presentation will unveil the next generation product SILASTIC™ SST 8860, which encompasses these benefits whilst demonstrating over 75% material recovery and reuse through advanced recycling and superior sealing performance. With the possibility of even faster processing at 40% lower coat weight compared to other self-seal products, this technology can coat a variety of tire sizes quickly, making it ideal for high-volume manufacturing. In addition, the talk will introduce a new range of silicone adhesives for silent tires, which are easy to use, offer high adhesion for foams during operation, and are fully removable at the end of tire life, enabling recycling.

Ligand-Regulated Dynamic Ionic–Coordination Networks in Epoxidized Natural Rubber for Self-Healing, Reprocessable, and Mechanically Recoverable Carbon Black–Reinforced Elastomers

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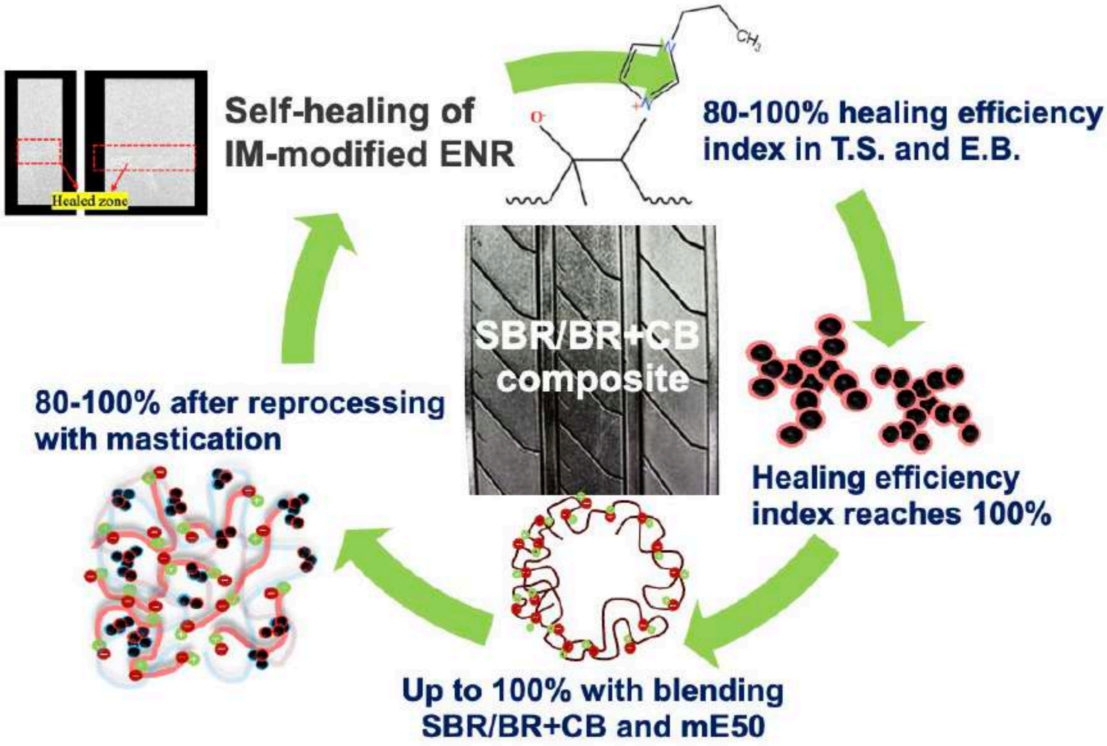
Abstract

The development of sustainable elastomers with simultaneous mechanical robustness, self-healing ability, and recyclability remains a major challenge in advanced rubber engineering. This work presents a ligand-regulated dynamic network strategy based on epoxidized natural rubber containing 50 mol% epoxide groups (ENR-50), designed to generate self-healing, relaxation recovery, and reprocessable elastomeric composites for carbon black (CB)-reinforced systems. Imidazole (IM), 2,6-diaminopyridine (DP), and ferric ions (Fe^{3+}) were incorporated to construct hybrid dynamic networks consisting of reversible imidazolium–epoxy ionic interactions, Fe–O coordination crosslinks, and controlled intermolecular spacing. The Fe^{3+} coordination network enhanced mechanical stability, while IM promoted reversible ionic interactions that facilitated molecular rearrangement, stress redistribution, and autonomous healing. DP increased free volume and segmental mobility, enabling improved relaxation behavior without significantly disrupting the coordination network. The modified ENR was employed as a functional modifier in CB-filled styrene–butadiene rubber (SBR)/butadiene rubber (BR) blends. Optimized compounding sequences promoted effective rubber–filler interactions while preserving dynamic network mobility. Mechanical and dynamic mechanical analyses demonstrated that the optimized composites achieved tensile strengths approaching 10 MPa with elongation at break exceeding 400%, together with excellent recovery after damage and reprocessing. Temperature scanning stress relaxation (TSSR) revealed broadened relaxation spectra associated with thermally activated reversible dissociation and reconstruction of ionic and coordination bonds. Remarkably, the composites exhibited healing efficiencies exceeding 100% based on modulus recovery. These findings demonstrate that ligand-regulated ionic–coordination networks provide an effective pathway toward durable, self-healing, and recyclable elastomers for advanced tire and engineering rubber applications.

Scheme I


Self-healing of
IM-modified ENR
Healed zone
80-100% healing efficiency
index in T.S. and E.B.
SBR/BR+CB
composite
Healing efficiency
index reaches 100%
80-100% after reprocessing
with mastication
Up to 100% with blending
SBR/BR+CB and mE50

Sustainable Natural Rubber-Based Waterborne Polyurethane: Advancing Adhesive and Coating Technologies

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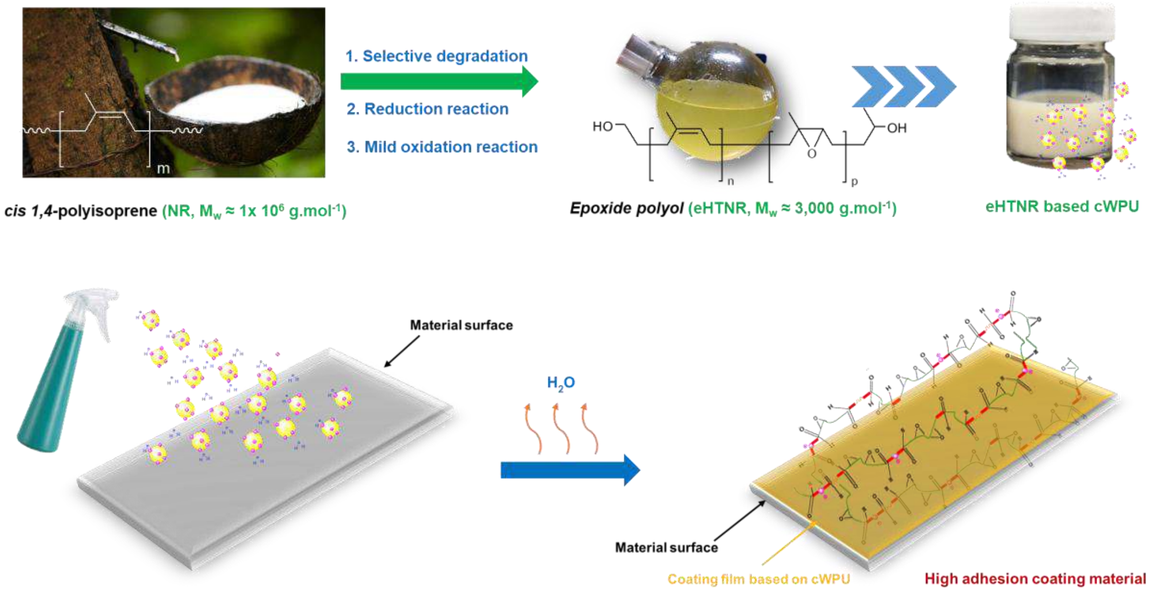
This study reports the synthesis and characterization of sustainable natural rubber (NR)-based cationic waterborne polyurethane (cWPU) adhesives and coatings derived from hydroxyl-terminated natural rubber (HTNR). HTNR with controlled molecular weights (1000–3000 $g \cdot mol^{-1}$) was synthesized via epoxidation, oxidative cleavage, and reduction, enabling its use as a renewable alternative to petroleum-based polyols. The cWPU dispersions were prepared through step-growth polymerization with a total solid content of approximately 20 wt%. Key formulation parameters—including cationic emulsifier content, chain extender concentration, HTNR molecular weight, NCO index, and epoxide functionality—were systematically investigated. The resulting cWPU latexes exhibited excellent colloidal stability, with particle sizes ranging from 60 to 453 nm and high positive zeta potentials (+50 to +70 mV). Incorporation of ethylene glycol significantly enhanced mechanical strength and reduced solvent swelling. Increasing NCO index and epoxide content induced a transition from elastomeric to more rigid film behavior. Adhesion performance on cow leather substrates demonstrated superior bonding strength compared to commercial adhesives. The optimal formulation, based on HTNR with a molecular weight of ~2000 $g \cdot mol^{-1}$ and 10% epoxide content, exhibited excellent lap shear and peel strength, particularly at a curing temperature of 70 °C. Enhanced adhesion is attributed to the high surface energy and cationic nature of the latex particles, promoting strong interactions with polar and negatively charged surfaces. These findings demonstrate the potential of NR-based cWPU as an eco-friendly, high-performance adhesive and coating for advanced industrial and leather applications.

Scheme I



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Development of Motion Detection Sensors from 3D Printed Natural Rubber and Nitrile Rubber Composites Filled with Barium Titanate and Conductive Carbon Black

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Abstract

Polymer-based flexible motion sensors have attracted considerable attention due to their wide range of potential applications. Natural rubber (NR) is a promising matrix for flexible conductive polymer composites because of its excellent elasticity and fatigue resistance [1]. Similarly, nitrile rubber (NBR) has gained research interest owing to its polarity, which promotes filler–matrix interactions and enhances electrical conductivity [2]. In this study, NR and NBR were used as polymer matrices filled with conductive carbon black (CCB) and barium titanate (BT) as hybrid functional fillers. The composites were fabricated using both casting and stereolithography (SLA) 3D printing techniques (Figure 1(A)). Electrical conductivity was evaluated using a Keysight E4990A impedance analyzer (Keysight Technologies, Malaysia), while the internal morphology was examined using an optical microscope (BEC-SF-4000-A, Becthai Bangkok Equipment & Chemical Co., Ltd., Thailand). The piezoresistive behavior of the composites was investigated under cyclic testing deformation at strain ranges of 0–50% and 0–100% to assess their motion-sensing performance (Figure 1(B)). The results showed that composites fabricated by 3D printing exhibited lower electrical conductivity than those prepared by casting. This was attributed to the disruption of the CCB conductive network during the SLA process, likely caused by UV laser exposure, which increased the electrical resistance [3]. This observation was supported by optical microscopy results. In terms of piezoresistive performance, NR composites prepared by casting showed lower sensitivity than those produced by 3D printing, whereas NBR composites exhibited the opposite trend. This behavior may be related to the higher polarity of NBR, which enhances its interaction with BT. Overall, both NR- and NBR-based CCB–BT hybrid composites demonstrated successful piezoresistive responses under tensile loading. These materials show strong potential for flexible sensor applications, including voice detection, structural health monitoring, and motion sensing.

Keywords: Natural rubber, Acrylonitrile butadiene rubber, Hybrid filler, 3D printing technique

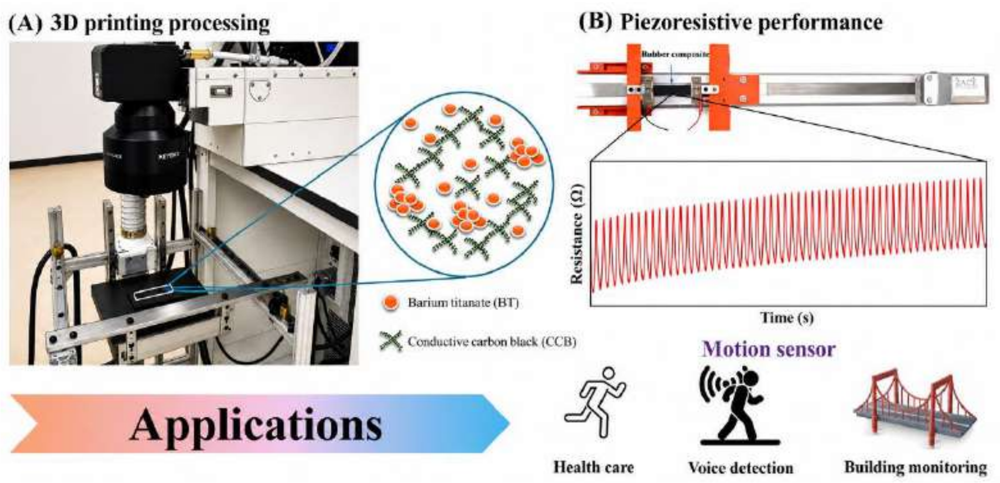

Figure 1 The three-dimensional (3D) printing processing (A), the experimental setup to elucidate the piezoresistive performance (B), and the application of rubber composites.

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Development of High-Strength Natural Rubber Films: A Comparative Study of Glutaraldehyde-Cured Modified Natural Rubbers

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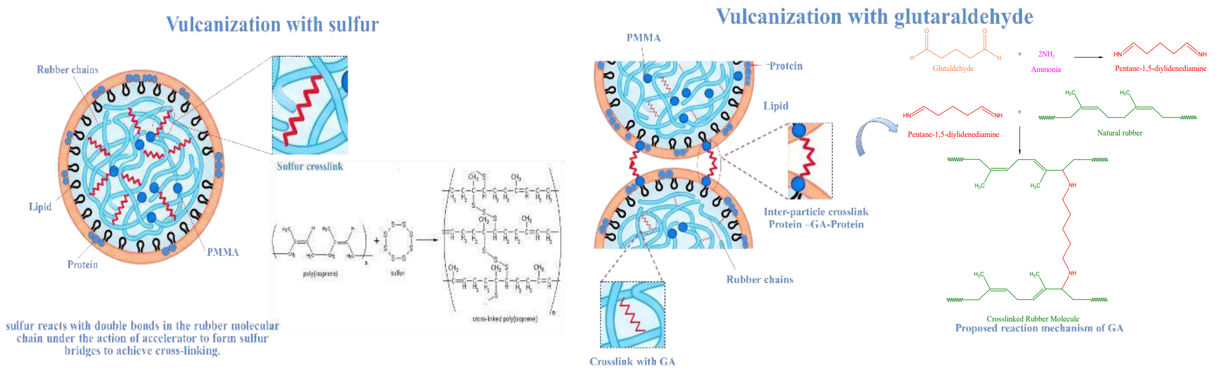
This study investigates the crosslinking reactions of modified natural rubbers specifically poly(methyl methacrylate)-grafted natural rubber (NR-*g*-PMMA) and epoxidized natural rubber (ENR) using glutaraldehyde (GA) as a curing agent. The molecular structures of the modified rubbers were successfully confirmed using Attenuated Total Reflection Fourier Transform Infrared Spectroscopy (ATR-FTIR) and Proton Nuclear Magnetic Resonance (NMR) with 10 wt% grafting (NR-*g*-PMMA) and 50 mol% epoxidation in ENR. Incorporating GA into NR-*g*-PMMA resulted in the highest mechanical properties, achieving a tensile strength (TS) of 20 MPa, compared to unmodified NR (5 MPa) and ENR (1 MPa). These results indicate that GA actively reacts with the amino functional groups introduced in NR-*g*-PMMA. In contrast, the cured ENR exhibited the lowest mechanical properties due to its depleted protein content and reduced double bonds. This confirms that reinforcing rubber films with GA depends on reactions with both amino groups and natural proteins, alongside the remaining double bonds. Furthermore, when compared to a traditional sulfur-curing system which failed to form coherent films due to severe cracking the GA-cured NR-*g*-PMMA system successfully produced intact, high-performance films. This work demonstrates that using NR-*g*-PMMA cured with GA holds significant potential for applications requiring both high modulus and high elongation at break.

Scheme I



Research Keyword: Natural rubber, Methyl methacrylate, Epoxidation, Glutaraldehyde, Vulcanization.

RETA 4th IC 2026

Speaker Session GM

Unlock Potential of Green Materials

Beyond Green Substitution: Engineering Functional Architectures from Natural Rubber and Biomass

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Abstract

Current developments in green materials often focus on replacing petroleum-based resources with renewable alternatives. However, future sustainable materials should not only originate from renewable resources, but also introduce new structural concepts and functionalities. This presentation discusses recent developments in natural rubber and biomass-based materials from the perspective of structural and architectural design.

The first part presents a fully plant-based leather alternative derived from pineapple leaf fiber (PALF) and natural rubber. Unlike conventional artificial leathers that rely on multilayer synthetic structures, the developed material consists of a single-layer fibrous architecture in which natural rubber is integrated within a randomly oriented PALF network. The resulting structure provides flexibility, strength, tear resistance, and desirable tactile properties while maintaining high bio-based content.

The second part highlights uniaxially aligned foam structures based on natural rubber and biomass-derived components. Through structural alignment and process innovation, lightweight materials with improved structural integrity, dimensional stability, and rapid elastic recovery can be achieved.

Overall, the presentation emphasizes that the future of green materials lies not only in sustainable feedstocks, but also in the intelligent design of structure, morphology, and processing. By combining natural rubber with engineered biomass architectures, new opportunities can emerge for advanced sustainable materials with enhanced functionality and reduced environmental footprint.

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Designing Plastic Solutions for an Uncertain World: Bioplastics and Circularity Solutions for a Resilient Future

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In today's rapidly evolving global landscape, the plastics industry faces increasing uncertainty driven by geopolitical disruptions, volatile energy supply, and rising sustainability demands. These challenges are reshaping how materials are sourced, designed, and managed throughout their lifecycle. This presentation focuses on designing plastic solutions that can adapt to these uncertainties through two complementary approaches: bioplastics and circularity-driven technologies. Bioplastics provide effective solutions for applications where plastic waste is difficult to collect, enabling controlled biodegradation and reducing environmental leakage. In parallel, recycling-based solutions play a critical role in enhancing the performance and value of post-consumer recycled materials, reducing dependence on virgin resources.

Case studies, including biodegradable agricultural films and innovative plastic modifier solutions for recycled polyethylene (PE) and polypropylene (PP), are presented to demonstrate real-world applicability. The C-Boost modifier enhances melt strength and mechanical performance in recycled PE, particularly stiffness and impact resistance. Meanwhile, the P-Boost modifier improves melt strength, thermal stability and overall mechanical properties in recycled PP, enabling these materials to meet more demanding application requirements and expand their potential use.

Rather than relying on a single approach, this work highlights the importance of designing adaptable, application-specific plastic solutions. Integrating material design, processing performance, and end-of-life considerations will be key to developing resilient and sustainable plastics systems for the future.

Toward Sustainable Flexible Materials: Biodegradable Thermoplastic Elastomers Based on PBAT/P(3HB-co-4HB) Dynamic Covalent Networks via Reactive Melt Processing

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Abstract

This study develops fully biodegradable thermoplastic elastomers (BTEs) based on poly(butylene adipate-co-terephthalate) (PBAT) and poly(3-hydroxybutyrate-co-4-hydroxybutyrate) [P(3HB-co-4HB)] blends through reactive melt processing with a dynamic covalent network strategy. Epoxidized soybean oil (ESO) was employed as a reactive compatibilizer and plasticizer, Peroxide initiated radical-mediated chain coupling, and boronic ester (BE) served as a dynamic crosslinker conferring vitrimer-like behavior. Peroxide progressively enhanced melt viscosity, storage modulus, and relaxation time; however, beyond an optimal concentration, competing chain scission limited further improvement. The synergistic combination of BE and DCP induced a morphological transition from dispersed-phase to co-continuous structure, sustaining elastic behavior in the molten state. The optimized formulation achieved a maximum elastic recovery of 76.01 ± 4.05% and elongation at break exceeding 1303%. Arrhenius analysis confirmed that increasing BE content reduced network rearrangement activation energy, enhancing dynamic bond exchange kinetics and melt reprocessability. For pilot scale study, one-step reactive extrusion outperformed two-step processing in morphology and mechanical properties, highlighting the importance of mixing sequence and residence time. Biodegradation testing per ISO 20200 over 268 days confirmed retained biodegradability through surface cracking, weight loss, and microbial colonization. This work establishes PBAT/P(3HB-co-4HB)/ESO/DCP/BE as a scalable platform for flexible, reprocessable, and environmentally friendly elastomers for industrial applications.

The Attractive Influence of Small Rubber Particles on The Green and Vulcanized Properties of Natural Rubber

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Abstract

Large rubber particles (LRP) and small rubber particles (SRP) were prepared from freshly tapped natural rubber (NR) latex with 0.6% ammonia by ultracentrifugation. The influence of particle sizes on the green and vulcanized properties of NR was investigated by mixing LRP and SRP at different ratios. Differences in the basic components and nature of LRP and SRP played significant roles in both green and cured properties. For green properties, modulus and tensile strength reached their highest values at an 80:20 w/w ratio (LRP:SRP), then declined when SRP exceeded 20% w/w. This promotion of tensile properties might be attributed to strain-induced crystallization (SIC) and good film formation efficiency. Additionally, the storage modulus (G') at the linear viscoelastic region (LVE) was directly proportional to SRP content, whereas LVE duration was disproportional. Regarding cure properties, rubber vulcanizates were prepared using a sulfur system. Properties including crosslinking density, tensile properties, and thermal aging resistance were highlighted. Higher protein content in samples with higher SRP resulted in higher crosslinking density, contributing to greater tensile properties. In summary, NR composed of LRP and SRP at a 70:30 w/w ratio enhanced the heat aging resistance of vulcanized NR efficiently.

Food Contact Assessment of PLA/NR/ TPS Ternary Blend Films for Food Packaging Applications

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Bio-based and biodegradable plastics have gained attention as sustainable alternatives to petroleum-based food packages. In the past, tough biobased and biodegradable packaging films produced by the blends of polylactic acid (PLA) and natural rubber (NR) have been reported [1] and the migration levels of all films were found to meet the EU standard for all food simulants under both short-term and long-term food contact conditions at 40°C [2]. Recently, ternary blends of polylactic acid (PLA), natural rubber (NR), and thermoplastic starch (TPS) has been proposed to reduce stickiness of PLA/NR films at high NR loading and to expedite biodegradation of the films under composting condition [3]. The addition of TPS raised a question of food-contact migration due to high hydrophilicity of TPS. In this work, the migration behavior of PLA/NR/TPS ternary blend films is assessed, focusing on the effect of TPS content and peroxide modification.

The TPS content was investigated at 10%wt (PNT10) and 30%wt (PNT30), while the effect of peroxide modification was investigated in PNT10 at 0 and 0.5%wt. Migration tests were conducted over time using 10% ethanol, 95% ethanol, and 3% acetic acid as food simulants for aqueous food, fatty food, and acidic food, respectively. The presentation will cover the effect of TPS content and peroxide modification on overall migration and the specific migration of TPS into food simulants over the periods outlined by OM0 and OM2 in Commission Regulation (EU) No 10/2011 standard for plastic materials and articles intended to come into contact with food.

Overall, this study highlights the critical role in controlling food-contact migration. These findings provide important insights for the development of sustainable food-contact packaging materials.

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Research Keywords
Thermoplastic starch (TPS), Polylactic acid (PLA), Natural rubber (NR), Migration study, Food contact materials

Speaker Session HT

Hub of Talents in Natural Rubber, NRCT

Development of Next-Generation Calcium Carbonate for Reinforcement of Natural Rubber Composites

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The increasing demand for green and sustainable materials has expanded across the global market. Among these materials, natural rubber (NR) is a renewable and biodegradable polymer widely used in various industrial sectors. Although NR exhibits excellent elasticity and flexibility, reinforcing fillers are still required to enhance its mechanical performance. The reinforcing efficiency depends not only on particle size, but also on filler dispersion and the compatibility between the filler and the NR matrix. Calcium carbonate ($CaCO_3$) is a low-cost and abundant mineral material naturally available in the environment. It can also be synthesized through a simple chemical precipitation method involving calcium ions (Ca^{2+}) and carbonate ions (CO_3^{2-}). Through this method, the crystal structure, particle shape, particle size, and surface properties of $CaCO_3$ can be controlled by adjusting parameters such as reactant concentration, mixing speed, and reaction medium.

In this study, spherical $CaCO_3$ particles with submicron particle size were successfully synthesized using $CaCl_2$ and $(NH_4)_2CO_3$ solutions, both without and with surface modification using olive soap to alter the surface polarity of the $CaCO_3$ particles. The mechanical properties of NR composites containing unmodified and modified $CaCO_3$ were investigated at filler loadings ranging from 0 to 60 phr. The results revealed that the NR composites filled with modified $CaCO_3$ exhibited higher tensile strength than those containing unmodified $CaCO_3$ and pure NR at all filler loadings. These findings suggest that the synthesized spherical $CaCO_3$ has strong potential as a next-generation reinforcing filler for sustainable NR composites with broader industrial applications.

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Transforming waste tires into high-efficiency CO_2 adsorbents through acid modification

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The growing concern over carbon dioxide (CO_2) emissions has prompted the search for sustainable solutions to mitigate their impact on the environment. This study explores the potential of repurposing waste tires, a significant environmental challenge, as efficient adsorbents for CO_2 capture. By utilizing an acid modification technique, waste tire powder is transformed into a high-performance CO_2 adsorbent [1,2]. The modification process enhances the material's surface properties, increasing its ability to adsorb CO_2. This approach not only provides an innovative solution to waste tire disposal but also contributes to the development of cost-effective and sustainable CO_2 capture technologies. The modified waste tire sorbent shows promising results in CO_2 adsorption capacity, demonstrating its potential for use in environmental applications. The study highlights the feasibility of converting waste materials into valuable resources for addressing global environmental challenges, aligning with the principles of circular economy and sustainability.

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Effects of surface-modified ultrafine fully vulcanized powdered natural rubber on the mechanical and thermal properties of polylactic acid composites

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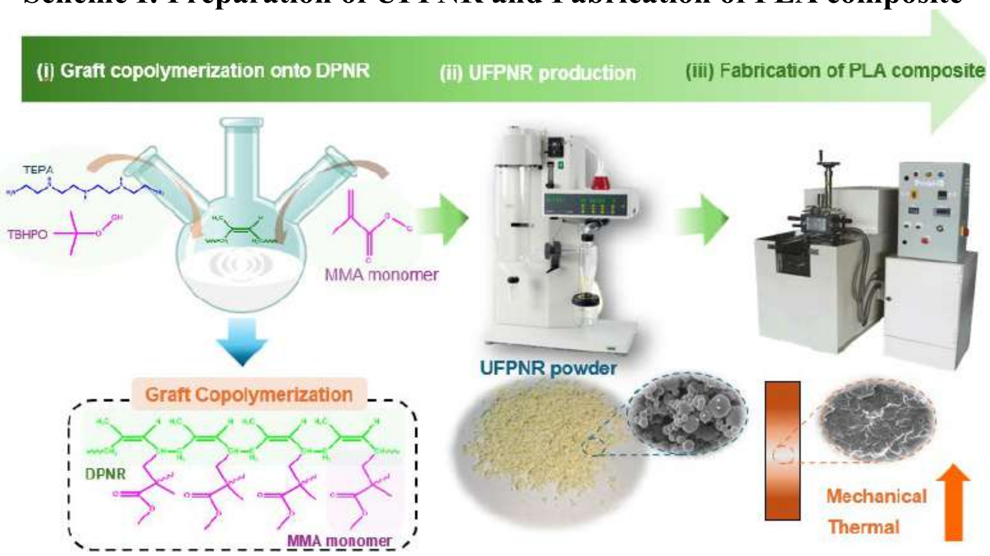
Abstract

Utilization of biodegradable thermoplastic polylactic acid (PLA) has restricted its widespread application because of the cost and brittle nature of materials. Therefore, this study focused on providing solutions to the brittle nature of PLA using a cost-effective and highly efficient filler material that could be assessed in abundance from agricultural industry. Firstly, different monomers were produced based on ultrafine fully vulcanized powdered natural rubber grafted methyl methacrylate monomer (UFPNR-g-PMMA) at various proportion. Secondly, the optimized UFPNR-g-PMMA powder was used as a toughening filler in the PLA matrix to produce the composite. Furthermore, flexural and impact strength tests were used to examine the toughening effects of the UFPNR-g-PMMA filler. The results recorded suggests that the aim of the study has been achieved considering that 3-4 and 2-3 folds improvements achieved with flexural strain and impact strength with the UFPNR-g-PMMA filler at 5-20 wt/wt%, respectively. Thermal stability of the PLA/UFPNR-g-PMMA composites has also improved drastically. The toughening performance exhibited by the UFPNR filler in the PLA matrix suggests its potential as an alternative material for 3D printing and packaging.

Scheme I: Preparation of UFPNR and Fabrication of PLA composite



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Sustainable fly ash waste in tire tread rubber: physical properties analysis and environmental impact evaluation

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This study investigates the utilization of fly ash (FA), a byproduct, to partially substitute zinc oxide (ZnO) as an activator in tire tread manufacturing. Minimizing ZnO lowers its environmental hazards, including the effects of ZnO leaching into aquatic environments during the tire's lifecycle. The FA was modified by including a rubber composite with and without ZnO, utilizing ZnO-to-FA ratios of 3:0 (control), 2:1, 1:2, 0:3, or 0:5 parts per hundred of rubber (phr). The findings indicate that crosslinking of the rubber composite transpired with FA, even in the absence of ZnO. Significantly, sample formulations with ZnO-to-FA ratios of 2:1 and 1:2 phr exhibited Δ torque values comparable to the control (3:0), facilitating ZnO reductions of 33.7% and 67.0%, respectively [1]. The efficacy is presumably attributable to metal oxides in FA, including CaO, MgO, Al_2O_3, and Fe_2O_3, which facilitate the vulcanization process. Furthermore, the tensile strength and modulus exhibited no variation. Elemental analysis revealed that a ZnO-to-FA ratio of 1:2 decreased zinc release by 63.0% relative to the control formulation. A comprehensive life cycle study indicated that substituting ZnO with FA in vulcanized rubber formulations diminishes environmental impacts, with the minimal effects noted at the 0:3 ZnO:FA ratio; nevertheless, an increased FA concentration may elevate consequences. The utilization of FA as a partial substitute for ZnO in tire tread processing demonstrates potential for mitigating environmental impact in tire production by diminishing zinc release, minimizing ecotoxicity, and fostering waste reduction via the recycling of fly ash.

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Utilization of π–π stacking interactions for improving carbon black dispersion in epoxidized natural rubber

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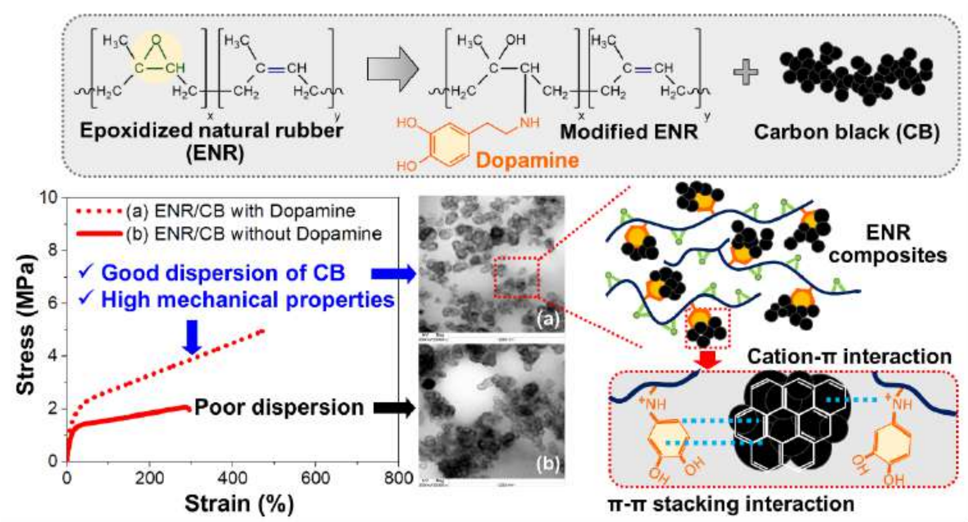
Natural rubber (NR) is derived from *Hevea brasiliensis* plants. NR exhibits good elasticity and mechanical properties. However, the oxidation is occurred due to the double bonds in molecules [1]. The epoxidation reaction is applied to modify NR, resulting in epoxidized natural rubber (ENR) [1]. In terms of rubber processing, carbon black (CB) aggregation is one of the important problems for rubber manufacturing [2]. The present research aims to solve the CB aggregation using the bio-inspired from mussel mechanism with aromatic interactions in ENR composites. Initially, the NR was chemically modified to obtain ENR. Then, the 20 phr of dopamine (D) was grafted onto the ENR chains. The CB content was various at 30, 40, and 50 phr, respectively. In this study, a variety of aromatic interactions (i.e. π-π stacking and cation-π interactions) were obtained between the benzene ring in D-grafted ENR chains and the surfaces of CB, which detected by FTIR and Raman spectroscopy [3]. Interestingly, the slope of SAXS/WAXS indicated that the CB particles were well dispersed in ENR matrix by the π–π stacking and cation–π interactions. These results were in good agreement with the TEM and RPA results [3]. Furthermore, the ENR/CB with dopamine exhibited the highest of the tensile properties and good energy-saving property due to the effect of CB reinforcement and the aromatic interactions. Finally, this research provides a novel approach based on a bio-inspired mechanism to solve the CB aggregation problem in rubber products, resulting in the ENR composites with superior performance properties.



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Speaker Session CC

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Translating Dynamic Crosslink Chemistry into Self-Healing Rubber Technologies: From Fundamental Mechanisms to Engineering Applications

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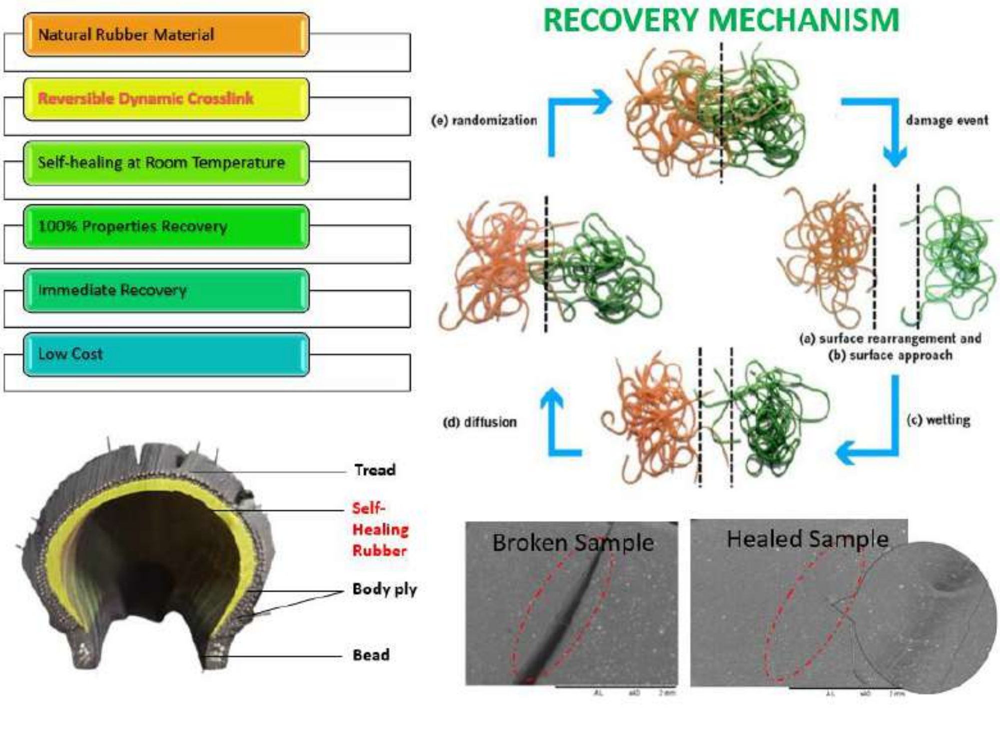
Abstract

The development of self-healing elastomers has emerged as a promising strategy to enhance durability, safety, and sustainability in rubber products. This research bridges fundamental polymer chemistry with practical engineering applications in elastomer technology. The work begins with the design of dynamic crosslink networks based on reversible metal–thiolate ionic interactions, which enable autonomous healing of rubber materials without external stimuli. Fundamental investigations were conducted to elucidate the formation of dynamic ionic networks, crosslink density, and molecular diffusion mechanisms responsible for healing behaviour. Building on this understanding, the research progressed toward engineering self-healing rubber systems through the incorporation of functional fillers, nanostructured reinforcements, and recycled rubber particles. These strategies were explored to optimize mechanical performance, healing efficiency, and structural stability in rubber composites. The concept was further extended to various elastomer architectures, including nanocomposites, foamed rubbers, and coated textile systems, demonstrating the versatility of dynamic crosslink chemistry in diverse material formats. Finally, the translational pathway culminates in the development of functional rubber technologies such as self-healing tapes and puncture-resistant tyre components. The findings highlight how fundamental insights into dynamic crosslink chemistry can be translated into innovative elastomer systems with real-world engineering impact, paving the way for next-generation durable and sustainable rubber products.



Development of Additives for Tailoring the Degradation of Polylactic Acid

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Polylactic acid (PLA) has emerged as one of the most promising bio-based and biodegradable polymers for sustainable plastic applications. However, its degradation behavior remains highly dependent on environmental conditions, and its relatively slow degradation rate under natural conditions remains a major limitation for broader utilization. This presentation highlights recent advances in the development of bio-based additives for manipulating the degradation behaviour of PLA. The study includes the use of oligoricinoleic acid (ORA), a renewable-resource-derived additive, to enhance the flexibility and accelerate the degradation of PLA [1], as well as investigations into the degradation behavior of PLA/thermoplastic starch blends under seawater conditions. In addition, the synthesis and effect of benzoxazine dimer on the degradation of PLA will also be discussed. These works highlight versatile additive engineering approaches for tailoring the degradation of PLA.

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Advancing Biobased Chitosan Biomaterials: From Hydrogels to Shape-Recovery Cryogels

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Chitosan-based biomaterials have evolved from composite hydrogels to advanced double-network (DN) systems and shape-recovery cryogels. A central theme across these studies is the use of star-shaped polycaprolactone (stPCL) to overcome the mechanical limitations and poor solubility of traditional chitosan-based materials. Initial research established that star-shaped architectures provide superior segment density and cross-linking efficiency compared to linear homologs, thereby enhancing the stability and mechanical properties of CS/stPCL composite hydrogels fabricated using EDC/NHS conjugation agents.[1] The research progressed into the development of double-network (DN) hydrogels using water-soluble carboxymethyl chitosan (CMCS) and modified poly(ethylene glycol) (PEG), successfully creating a hybrid ionic/covalent system with high shear modulus and bioactivity.[2] Further research led to the fabrication of CS-based networks via urethane/urea linkages, demonstrating that incorporating stPCL significantly improves compressive strength and flexibility while maintaining cell viability above 70%.[3] The most recent development in this work involves chitosan-based cryogels cross-linked through hydrogen-bond interactions with urethane-modified PCL (PCLU). This approach simplifies the fabrication process while introducing rapid shape recovery and a macroporous structure essential for cell infiltration.[4]

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3,4-Dihydro-1,3,2H-Benzoxazine: Various Applications of Basic Monomers

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Abstract

Benzoxazine monomers (3,4-dihydro-1,3-2H-benzoxazines) are heterocyclic compounds consisting of fused benzene and oxazine rings, typically synthesized via the Mannich reaction from primary amines, paraformaldehyde, and phenols[1]. A wide variety of benzoxazine monomers has been developed, serving as key precursors for polybenzoxazines with tunable properties for advanced applications[2].

Beyond their conventional role, benzoxazine monomers have recently emerged as multifunctional materials. They can act as ligands for rare-earth ions such as Ce(III), forming complexes that serve as precursors for CeO_2, in catalytic reforming systems[3-6]. Remarkably, despite lacking classical reducing groups, they exhibit intrinsic reducing ability toward precious metal ions such as Ag(I)[7,8], enabling the formation of metal-coated substrates including TiO_2, SiO_2, carbon black, chitosan, and poly(vinyl alcohol)[9-12]. These materials, particularly Ag–TiO_2, have been incorporated into poly(lactic acid) (PLA) to produce golden, antibacterial fibers and fabrics[13].

Benzoxazine monomers also display intrinsic luminescence under UV irradiation, as first observed by our group[14]. Building on this, poly(acrylic acid)-grafted benzoxazines (PAA-g-BZX) were synthesized and used as luminescent additives for PLA, enabling 3D printing of golden filaments with green emission without inorganic phosphors[15]. Furthermore, benzoxazines can initiate ε-caprolactone polymerization to form functional additives that enhance fluorescence and mechanical properties[16]. Their complexation ability also improves processability in stereolithography (SLA) and enhances dielectric performance[17,18].

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Hydrolysis of Dipeptides and Polyamides Catalyzed by Acid-Base Bifunctional ZrO_2-Based Materials

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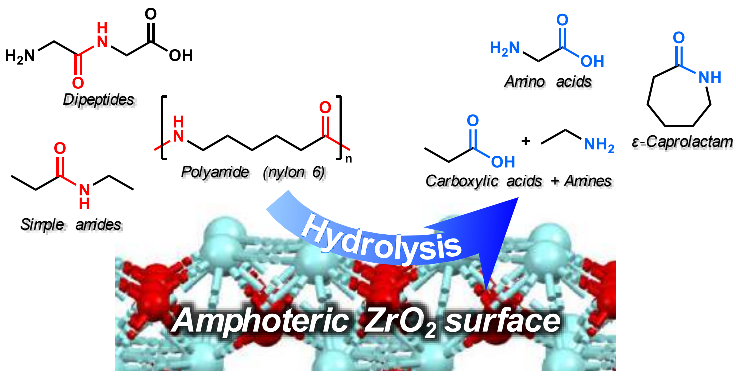
Amide bonds are ubiquitous in small organic compounds, proteins, and engineering plastics such as nylons and aramids). In the latter two categories, catalytic hydrolysis represents an attractive approach for yielding their building blocks from the perspectives of biorefinery and chemical recycling of plastics. However, because the hydrolysis products contain amino and carboxylic acid functional groups, conventional strong acids and bases—typical catalysts for hydrolyzing chemical bonds—are readily deactivated through neutralization by acidic or basic products; consequently, neither strong acids nor strong bases function effectively as catalysts for hydrolyzing amide bonds. Therefore, the development of well-designed catalysts is required for the efficient hydrolysis of amide bonds in proteins and polyamides.

In the hydrolysis of glycylglycine (Gly-Gly) as a model reaction, we found that monoclinic ZrO_2 (m-ZrO_2) functions as an efficient catalyst, producing glycine in up to 97% yield with only a small amount of glycine anhydride under optimized conditions.[1)] In stark contrast, conventional homogeneous acidic and basic catalysts, such as H_2SO_4 and NaOH, exhibited markedly inferior performance. NH_3- and CO_2-temperature-programmed desorption (TPD) measurements indicated that the acid-base bifunctionality of m-ZrO_2 plays a crucial role in the Gly-Gly hydrolysis. Furthermore, the m-ZrO_2 catalyst exhibited a broad substrate scope. Various dipeptides containing acidic or basic amino acid residue(s) were successfully hydrolyzed into their corresponding components at 373 K. In addition, nylon 6 was hydrolyzed into ε-caprolactam (81% yield) and ε-aminocaproic acid (13%) at 503 K, which is significantly lower than the temperatures previously reported for the hydrolysis of nylon 6 (≥573 K).



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Design of Geometric and Electronic Environments Using Metal Clusters for Highly Efficient Catalysis

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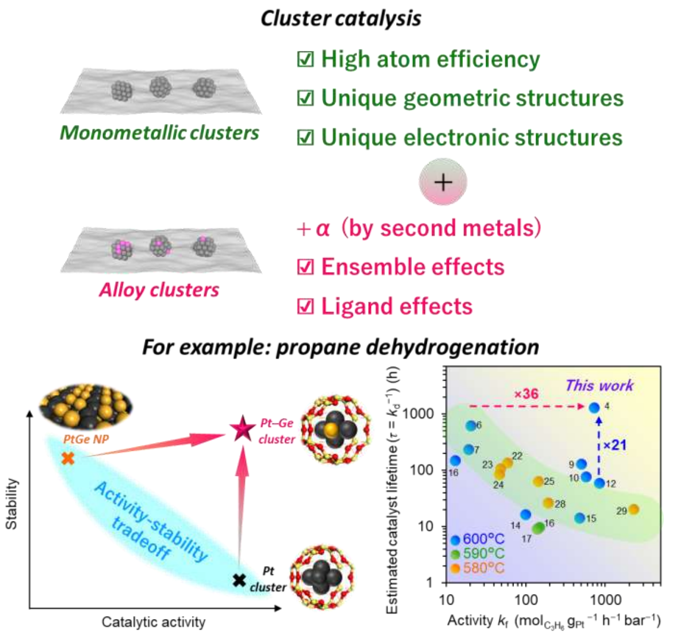
Abstract

Metal clusters have increasingly attracted attention as efficient catalysts due to their high proportion of accessible surface sites and unique geometric/electronic structures that distinguish them from both single-atoms and nanoparticles [1]. However, metal clusters possess an inherent tendency to sinter during pretreatment or reaction conditions, often irreversibly, driven by the minimization of their surface energies. Furthermore, conventional approaches often lack a deep understanding of the optimal cluster environment, hindering the rational catalyst design of high-performance catalysts.

To address these challenges, we have developed synthesis strategies for small clusters and investigated catalytic performance in hydrocarbon upgrading reactions. In this presentation, we introduce the recent advancements in highly efficient catalysts for styrene hydroformylation, propane dehydrogenation, and the non-oxidative coupling of methane, and *etc*. For instance, we discovered that Rh clusters larger than 1 nm serve as optimal structures for the hydroformylation of styrene Kinetic and theoretical analyses revealed that these Rh clusters provide a specific environment that facilitates the balanced co-adsorption of styrene, CO, and H, thereby promoting hydroformylation. In propane dehydrogenation, the synergistic effect of downsizing Pt species from the nanometric to the subnanometric regime and alloying with Ge allowed to break the activity–stability tradeoff [2]. We will discuss about the structural analysis, catalysis, and theoretical insights into hydrocarbon upgrading reactions.

Scheme I



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Influence of Simultaneous Biaxial Stretching on the Structure and Performance of PLA-Based Blend Films

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Abstract

Polylactide (PLA)-based biodegradable films have attracted significant attention as sustainable alternatives to conventional petroleum-based packaging materials because of their bio-based origin, transparency, and good processability. However, the inherent brittleness and low toughness of PLA limit its application in flexible packaging. Blending PLA with other components is considered an effective approach to improve flexibility, although phase separation and weak interfacial adhesion often limit the overall performance improvement.

Recently, simultaneous biaxial stretching at high stretching rates has emerged as an effective processing technique for improving the toughness and mechanical balance of PLA-based films through molecular orientation and microstructural control. In this work, blend modification and simultaneous biaxial stretching were integrated to develop high-performance PLA-based biodegradable films. The effects of phase morphology and strain-induced crystallization on structural development, mechanical properties, and oxygen barrier performance were investigated. Biaxial stretching promoted molecular alignment and crystallization, leading to enhanced toughness, dimensional stability, and barrier properties. The results demonstrate that combining blend design with biaxial orientation is a promising strategy for developing biodegradable films for sustainable packaging applications.

Research Keyword: Biodegradable film, Polylactide, Biaxial stretching

Polymerization of Arynes Initiated by a Nitrogen Nucleophile

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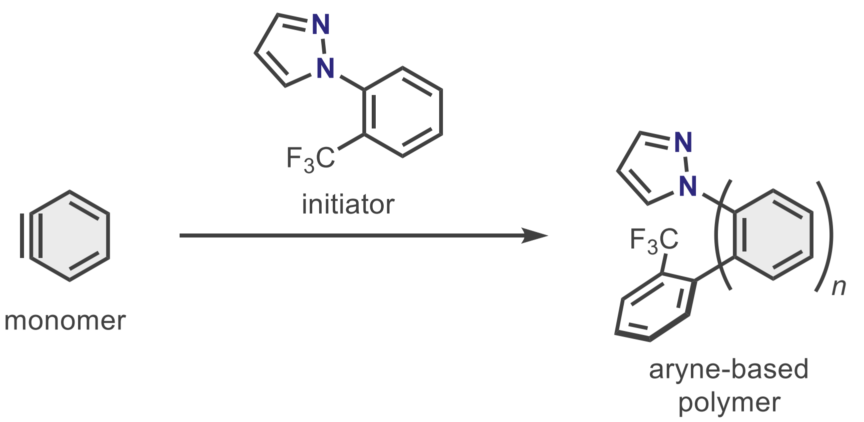
Arynes are attractive monomers for the direct incorporation of *o*-arylene units into polymer backbones, but their extremely high reactivity and short lifetimes have limited their use in polymer synthesis.[1-3] We have studied nitrogen-nucleophile-initiated aryne polymerization as a strategy to address this challenge. First, we found that *N*-aryl pyrazoles initiate nucleophilic aryne polymerization to give poly(*ortho*-arylene)s, providing a direct synthetic route to sterically congested *o*-arylene-based polymers.[4] The polymerization proceeds via a Truce–Smiles rearrangement pathway, and the persistent pyrazole active site suppresses undesired chain termination and chain transfer. We then extended this concept to copolymerization and achieved alternating copolymerization of arynes with carbonyl compounds by using nitrogen nucleophiles as initiators. This method enables direct construction of polymers containing both *o*-arylene units and carbonyl-derived linkages from highly reactive aryne monomers. These results demonstrate that nitrogen-nucleophile initiation offers a versatile platform for aryne-based polymerization, enabling both homopolymerization and alternating copolymerization. This study expands the scope of aryne polymerization and provides a new strategy for the synthesis of structurally unique aromatic polymers.



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Machine Learning-Driven Identification of Polymer Accumulation Hotspots and Targeted Intervention Strategies in Tropical River Systems

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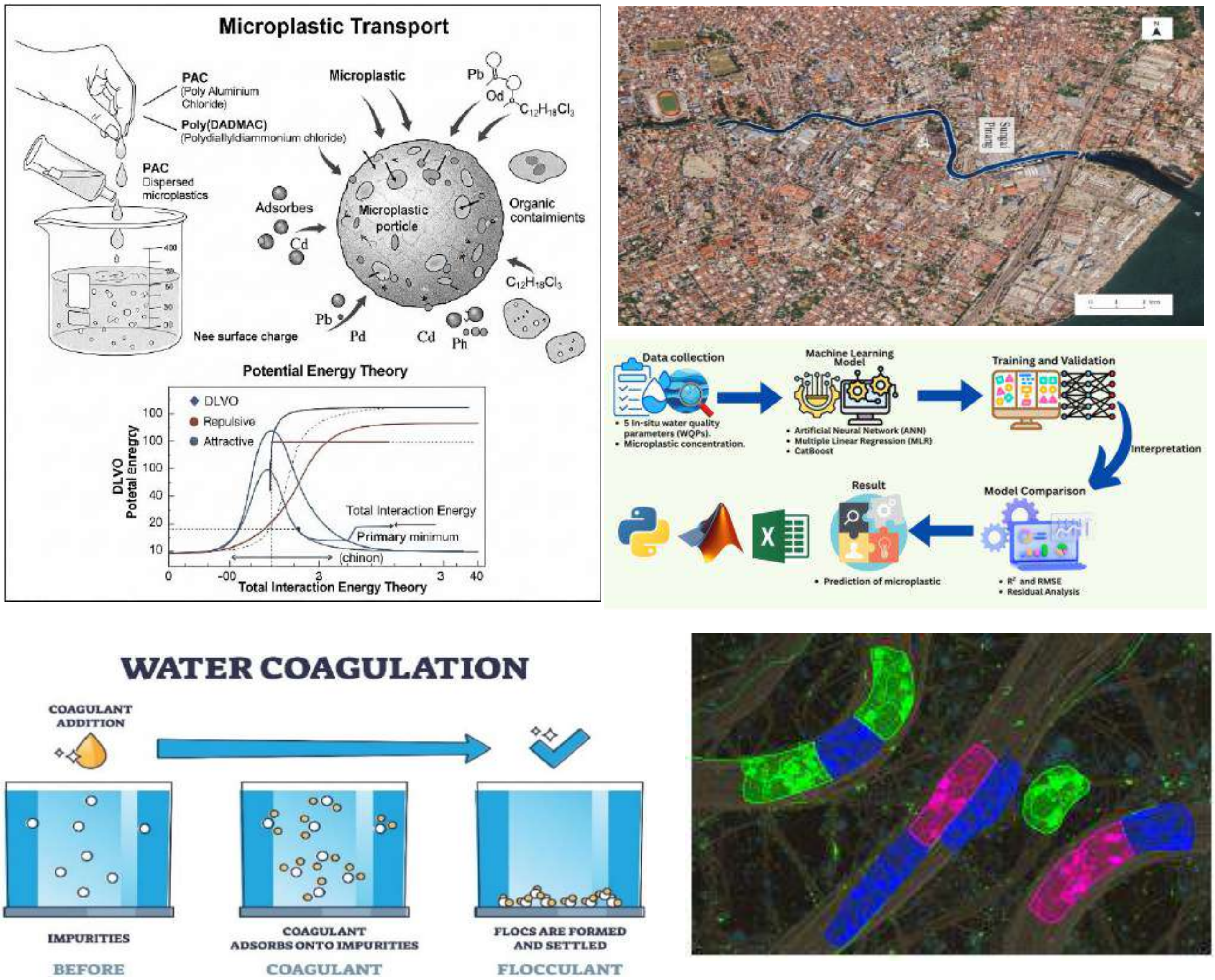
Abstract

Polymer-based microplastic particles in freshwater systems represent a critical challenge for sustainable material management, particularly in tropical urban rivers characterised by complex hydrodynamics and diverse anthropogenic inputs. While existing studies predominantly focus on abundance and morphological classification, limited attention has been given to understanding how polymer properties govern spatial accumulation and how this knowledge can be translated into targeted intervention strategies. This study presents a data-driven framework integrating spatial hotspot analysis and machine learning to identify polymer accumulation zones in Pinang River, Malaysia. Field-based characterisation revealed the dominance of fibrous and fragmented polymers, primarily polyethylene and polypropylene, with distinct hotspot formation associated with urban discharge points and hydrological variability. Spatial statistical analysis was applied to identify significant clustering patterns, representing key polymer leakage pathways within the river system. To enhance predictive capability, machine learning models were developed using physicochemical water quality parameters and spatial attributes to estimate microplastic distribution and hotspot probability. To further interpret these system-level observations, mechanistic and coagulation studies were conducted to evaluate particle behaviour and removal efficiency using polyaluminium chloride (PAC) and polydiallyldimethylammonium chloride (PolyDADMAC). The results indicate that polymer properties, including morphology and aggregation behaviour, play a critical role in governing both environmental distribution and treatment performance. The integration of hotspot identification, predictive modelling, and treatment evaluation provides a framework for targeted intervention, enabling more efficient resource utilisation and supporting circular wastewater management strategies. This framework contributes to ongoing international efforts in plastic resource circulation and sustainable water management under collaborative research initiatives.

Scheme I



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Development of Renewable Biodegradable Copolyester using Isosorbide

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Isosorbide is known as bio-derived secondary diol, that can be used to synthesize various polymers, including polyesters, polycarbonates, and polyurethanes. Specially in biobased polyester synthesis, isosorbide can be combined with different diacids to obtain polymers with enhanced properties. The unique structure of this molecule, consisting of two fused rigid furan rings, offers wide scopes for researchers. As a result of being a rigid molecule, isosorbide imparts good properties to polymers in both mechanical and thermal prospects. Recently, incorporation of isosorbide into aliphatic structures such as polybutylene succinate (PBS) was encountered as a promising strategy to overcome the limitation associated with poor mechanical, thermal and biodegradable properties of such polymers. Addition of isosorbide into an aliphatic chain enhance the mechanical properties and thermal properties without effecting its biodegradability. Although the properties of random copolymer of PBS and Poly(isosorbide succinate) (PIS) were analyzed, the block copolymer remains unexplored. This study, for the first time, synthesizes a PBS/PIS block copolymer. The blend of PLA with block copolymer improved thermal stability while random copolymer exhibited better mechanical properties. Polymer films containing isosorbide exhibited faster degradation compared to PLA/PBS and neat PLA in both lipase and protease enzymatic solutions.

Functionalization of Polymer Materials Based on Lignin Backbones for Resource Circulation

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The development of polymer materials compatible with resource circulation is essential for achieving a sustainable society, particularly in light of the increasing demand for high-performance materials with controlled end-of-life behavior. Conventional polymer systems often exhibit either excellent durability or degradability, but rarely both, creating a fundamental challenge in materials design[1]. In this study, polymer materials based on lignin backbones were designed from two complementary perspectives: photothermal functionality and chemically controlled degradability, aiming to integrate performance during use with efficient deconstruction after use (Figure 1).

First, a photothermal adhesive system was developed by incorporating lignin into a polyester-based hot-melt adhesive, exploiting its intrinsic ability to convert absorbed light into heat. Upon near-infrared (NIR) irradiation, the lignin-containing adhesive exhibited a rapid and significant temperature increase, enabling efficient debonding through thermal softening. In contrast to the pristine adhesive, the lignin composites not only retained but also enhanced adhesion strength, while allowing on-demand dismantling triggered by external stimuli. This simple material design demonstrates a practical strategy for reversible bonding without complex chemical modification.

Second, a degradable polymer system was designed by introducing lignin-inspired structural motifs into aromatic polyethers. Specifically, benzil and hydrobenzoin units, which mimic the β-1 linkage found in lignin, were incorporated into the polymer backbone. Under oxidative conditions, these polymers underwent selective bond cleavage, as confirmed by spectroscopic analysis, resulting in the formation of lower-molecular-weight species. The degradation behavior is attributed to the cleavage of diketone and diol structures, providing a controllable pathway for polymer decomposition.

Overall, this study demonstrates that lignin-derived structural and functional features can be effectively leveraged to construct polymer systems that combine mechanical robustness, stimulus responsiveness, and controlled degradability. The integration of photothermal debonding and chemically triggered degradation offers a versatile platform for designing sustainable polymer materials. This work provides a molecular-level design strategy toward advanced materials that bridge the gap between durability in service and degradability after use, contributing to the realization of circular material systems.

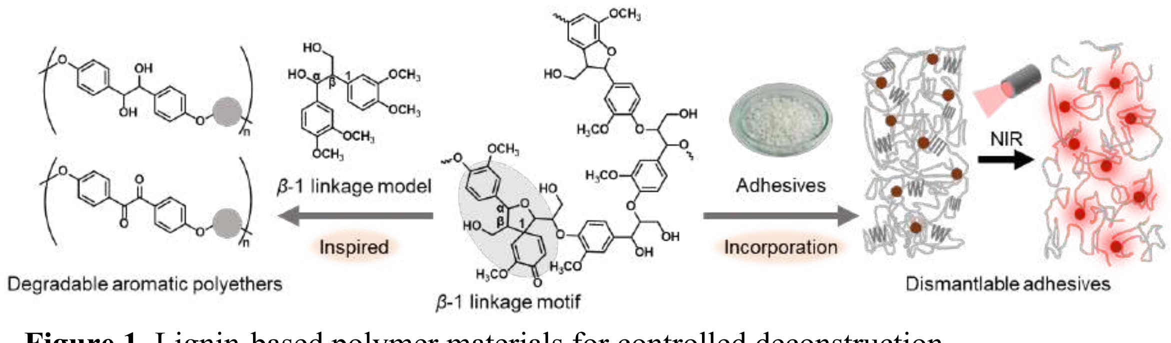

Figure 1. Lignin-based polymer materials for controlled deconstruction.

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Retarding Retrogradation in Polylactide/Thermoplastic Starch Films through Disulfide Chemistry and Biaxial Orientation

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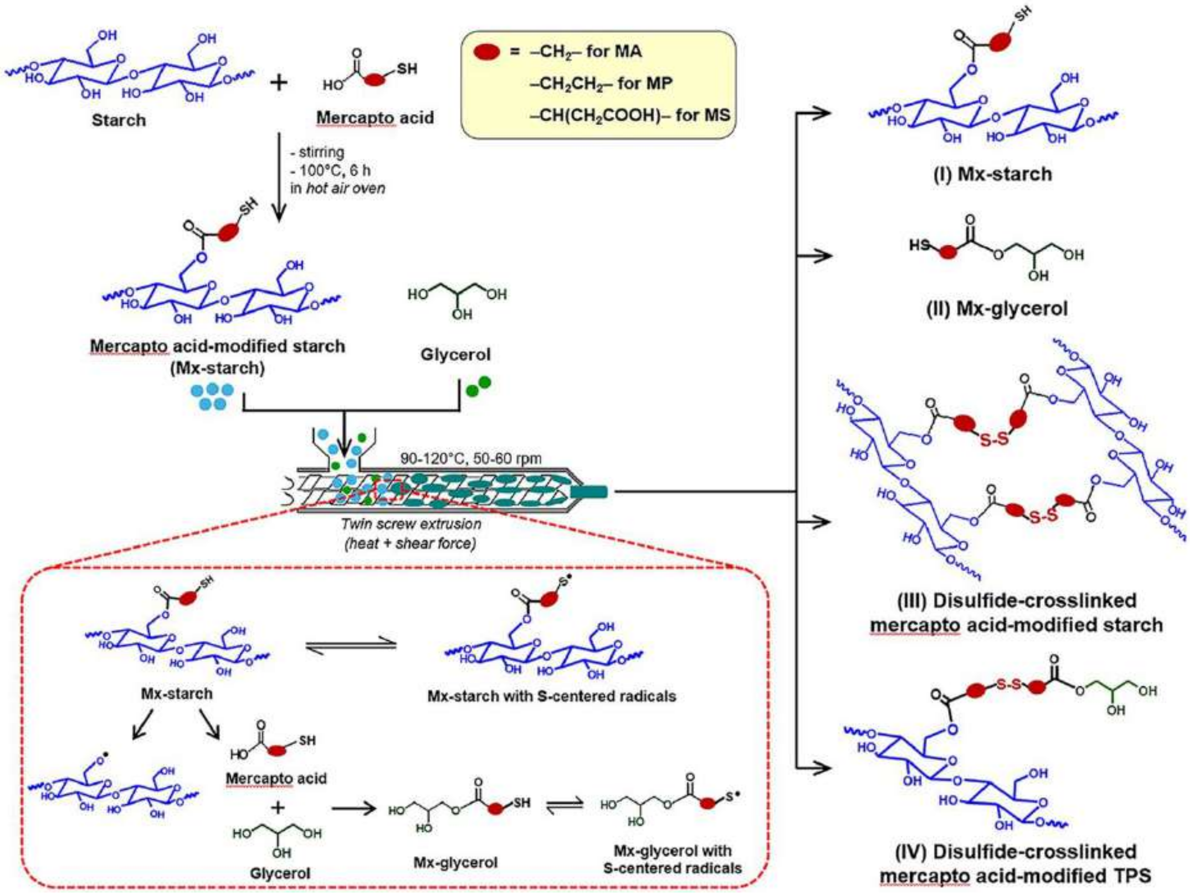
Abstract

Thermoplastic starch (TPS) is a promising renewable and biodegradable material for sustainable packaging; however, its practical use is restricted by retrogradation, plasticizer migration, moisture sensitivity, and limited compatibility with hydrophobic biodegradable polymers. This study proposes a solvent-free processing strategy to stabilize TPS in polylactide (PLA)-based films by integrating mercapto acid-enabled chemical modification with biaxial orientation. Cassava starch was modified with mercapto acid derivatives and plasticized with glycerol through reactive extrusion to produce crosslinkable modified TPS (Mx-TPS). The Mx-TPS was subsequently melt-blended with PLA and processed into biaxially oriented PLA/Mx-TPS films. During melt processing, thiol groups promoted disulfide linkage formation and partial glycerol immobilization, while biaxial stretching induced PLA crystallization and lamellar alignment. These combined effects restricted starch chain reassociation and suppressed V_H-type starch crystallization during storage. Among the investigated modifiers, mercaptosuccinic acid (MS) provided the most effective stabilization, attributed to enhanced interfacial interactions and reduced molecular mobility. The resulting BO-PLA/MS-TPS films exhibited improved moisture resistance, oxygen barrier performance, water vapor barrier performance, and tensile properties compared with unmodified BO-PLA/TPS films. Oxygen permeability decreased from 1,153.72 to 589.31 cc.mil/m^2.day.atm, while water vapor permeability decreased from 159.21 to 68.90 g.mil/m^2.day.atm. These results demonstrate that combining dynamic disulfide chemistry with orientation-induced crystallization is an effective route to retard TPS retrogradation and improve the long-term performance of biodegradable PLA/TPS films for sustainable packaging applications.

Scheme I

Proposed mechanism of disulfide bond formation in mercapto acid-modified thermoplastic starch (Mx-TPS) during melt extrusion



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Synthesis and Characterization of Thermoresponsive Chitosan–Aloe Composite as an Injectable Hydrogels

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Abstract

This study reports the synthesis and characterization of thermoresponsive chitosan and Aloe composite as an injectable hydrogel. Phosphorylated chitosan (PCTS) was first synthesized using a phosphorus pentoxide/methanesulfonic acid system [1], followed by conjugation with isobutyric acid (ISB) to yield PCTS-ISB, in which the hydrophilic–hydrophobic balance drives thermoresponsive behavior. Structural confirmation by NMR spectroscopy verified successful ISB substitution onto the chitosan backbone, while Dynamic Light Scattering (DLS) demonstrated a temperature-dependent increase in particle size. To enhance bioactivity, PCTS-ISB was combined with fresh *Aloe vera* juice, which naturally contains acemannan, a mannose-based polysaccharide recognized for its wound healing and tissue regeneration properties [2]. The sol-gel transition behavior of the PCTS-ISB/Aloe composite was evaluated by the tube tilting method, revealing a phase transition at approximately 37°C, corresponding to physiological temperature. These findings demonstrate that the PCTS-ISB/Aloe composite holds strong potential as a minimally invasive injectable hydrogel system capable of forming a desired shape *in situ*, with promising applications in tissue engineering.

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Speaker Session ST

SATREPS

Science and Technology Research Partnership for Sustainable Development

Evaluation of Rubber Seed Production Capacity and the Impact of Seed Harvesting on Greenhouse Gas (GHG) Fluxes in Para Rubber Plantations

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Abstract

Para rubber (Hevea brasiliensis) seeds are a highly promising, underutilized biomass resource. Establishing sustainable pathways for their industrial utilization (biochemicals, bioplastics, bioenergy) is vital for the SATREPS circular economy framework. In addition, large-scale harvesting may alter nutrient cycling and soil carbon input, shifting greenhouse gas (GHG) dynamics. This research aims to evaluate regional seed production across Thailand and assess the effect of seed removal from the soil surface on soil-surface GHG fluxes.

This research mainly consists of two phases.

1. Potential seed production: Field investigations at model farms in Chonburi and Nakhon Si Thammarat will quantify annual seed yields across various tree ages and varieties. Simultaneously, canopy phenology will be analyzed using UAV and satellite remote sensing to develop a nationwide yield estimation model.

2. GHG fluxes: In-situ soil GHG (CO_2, CH_4) emissions will be measured at a model site in Chachoengsao, comparing experimental plots with natural seed and litter retention (control) to those with systematic seed removal (simulating harvesting).

Based on empirical data, we will estimate the potential availability of rubber seeds in Thailand, accounting for seasonal variations, tree ages, and varieties. Additionally, we will construct a predictive model to simulate soil GHG dynamics in response to changes in seed-harvesting intensity. This research provides a critical scientific baseline for SATREPS, helping stakeholders optimize the utilization of rubber seeds for green energy and materials while minimizing the carbon footprint of natural rubber production.

Rubber Plantations as a Carbon Sink for Thailand's Net-Zero Goals

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As the world's largest natural rubber producer, Thailand is transforming its extensive rubber sector—covering approximately 3.8 million hectares of plantations—into a major carbon sink to help offset industrial emissions, while advancing low-carbon manufacturing to comply with evolving global trade regulations. Rubber plantations function as natural carbon sinks by storing carbon in both vegetation and soil. In 2022, Thailand's rubber vegetation contributed to a net CO_2 removal of 91,486.96 ktCO_2eq, representing around 85% of total net removals in the LULUCF sector and offsetting nearly 24% of the country's total emissions [1]. Although soil carbon sequestration in rubber plantations is also expected to be substantial, it has not yet been officially quantified or reported.

However, carbon losses associated with rubber wood harvesting could become a major source of future CO_2 emissions, as a large proportion of existing plantations is projected to be harvested within the next 25 years. This potential challenge to Thailand's net-zero targets could be reduced through the adoption of low-frequency tapping systems, which extend the rotation age of rubber plantations and enhance long-term carbon storage. Furthermore, carbon absorbed during the lifespan of rubber trees can remain sequestered in harvested wood products such as timber, furniture, and construction materials, thereby keeping CO_2 stored outside the atmosphere for decades.

To better understand the physiological processes underlying carbon sequestration in rubber plantations and their potential responses to climate change, our study measured CO_2 and water fluxes across three major rubber-growing regions using the eddy covariance technique. Annual net carbon removal, expressed as net ecosystem production (NEP), averaged 37 tons of CO_2 per hectare per year.

Net ecosystem production (NEP) of rubber plantation measured by eddy covariance method.

Plantation age (year)	4	5	6	7	8	9	17	18	19	20	21	22	23	24	25	
NEP (Kg CO_2/rai/yr)	1,843	4,078	5,487	3,555	7,760	5,444	7,643	5,027	4,485	6,496	6,900	5,621	8,122	8,181	8,176	Kg CO_2/rai/yr
NEP (Tons CO_2/ha/yr)	11.5	25.5	34.3	22.2	48.5	34.0	47.8	31.4	28.0	40.6	43.1	35.1	50.8	51.1	51.1	Tons CO_2/ha/yr
Site: Bungkan	29.3															Tons CO_2/ha/yr
Site: NakonSritammaracha							39.6									Tons CO_2/ha/yr
Site: Chachengsao									42.8							Tons CO_2/ha/yr
Site: Chachengsao									36.7				51.0			Tons CO_2/ha/yr
All 3 sites (15 years)	37.0															Tons CO_2/ha/yr

Reference 1) Biennial Transparency Report. 2024. https://unfccc.int/documents/645098

Establishment of Process Flow Diagram for Extraction, Refining, and Chemical Conversion of Rubber Seed Oil – Overview of Subject 2 in SATREPS Program –

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The SATREPS program, which is being conducted jointly by Thailand and Japan, aims to develop the utilization technology of rubber seeds for green products to mitigate global warming and plastic pollution. Subject 2 primarily aims to extract crude oil from rubber seeds, refine it, and then convert it into various biochemicals. Furthermore, it also envisions extracting trace components from the leftover residue and converting it into fuel through pelletization. Participating organizations on the Thai side are Chulalongkorn University (CU), Kasetsart University (KU), and Walailak University (WU), while on the Japanese side are Tokyo University of Agriculture and Technology (TUAT) and Osaka Metropolitan University (OMU).

Crude oil recovery from rubber seeds is carried out in KU with a mechanical optimized oil pressing methods. Biomass pellets and biochar are also produced from outer shell and cake. Crude oil purification is conducted with both conventional technique and novel adsorption using modified active carbon produced from biochar (WU). CU has responsibility for compositional analyses of feed/product streams from each step in crude oil extraction and purification as well as the precise fermentation for production of fatty acid derivatives.

In TUAT, a process to convert the unsaturated fatty acid components abundant in rubber seed oil into dimer acids and branched saturated fatty acids is established. In OMU, a method for enhancing the stability of fatty acid esters derived from rubber seed oil is established and their potential applications in bioenergy is explored.

Precision Fermentation of Rubber Seed Oil Extracts for Fatty Acid Derivative Production: From Substrate Valorization to Scalable Bioprocesses

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Rubber seed oil (RSO), an abundant agro-industrial by-product of Southeast Asia's rubber plantations, represents an underutilized yet chemically rich feedstock for biotechnological valorization. Rich in C18 polyunsaturated fatty acids — including oleic (C18:1, ~24.6%), linoleic (C18:2, ~39.6%), and linolenic (C18:3, ~16.3%) acids — RSO offers a compelling low-cost, renewable substrate for the microbial production of high-value fatty acid derivatives.

This talk presents an integrated approach to RSO valorization through precision yeast fermentation, with emphasis on the oleaginous yeast *Yarrowia lipolytica* as a metabolic chassis for converting RSO-derived lipids into value-added products including biosurfactants, structured lipids, and functionalized fatty acid esters. We highlight upstream substrate engineering strategies — encompassing degumming, deacidification, and peroxide reduction — that are critical for generating a fermentation-compatible RSO extract, followed by rational strain and process optimization to redirect carbon flux toward target fatty acid derivatives.

Key bioprocess considerations — including fed-batch fermentation design, nutrient-to-oil feeding strategies, and dissolved oxygen management — that govern productivities and titers at bench scale are discussed. Critically, we address the scale-up challenges inherent to oil-based fermentation systems, including emulsification, mass transfer limitations, and downstream recovery, drawing from our laboratory's experience in transitioning lipid fermentation processes from flask to pilot-scale bioreactors.

This work demonstrates the feasibility of RSO as a platform feedstock within a yeast-based biorefinery framework, contributing to both circular bioeconomy goals and Thailand's natural rubber value chain.

Comprehensive Valorization of Rubber Tree Seeds

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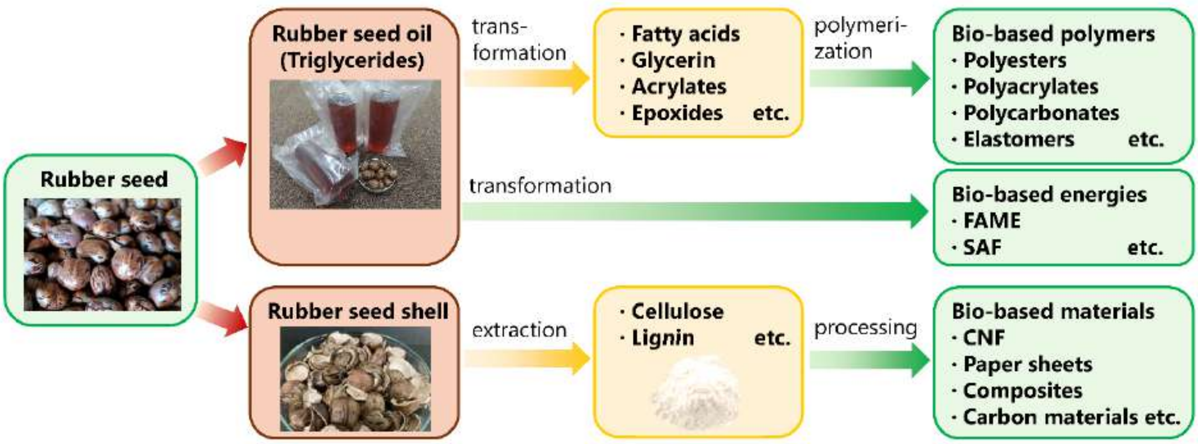
Rubber tree seeds are an abundant yet underutilized biomass resource generated in large quantities in rubber plantations. Although rubber plantations are primarily cultivated for latex production, rubber seeds are often discarded or used only for low-value applications. This project focuses on the integrated utilization of rubber seed oil (RSO) and rubber seed shell (RSS) for the development of sustainable materials and biodiesel fuels.

RSO contains a high proportion of unsaturated fatty acids , making it a promising renewable feedstock for the synthesis of bio-based functional polymers and alternative fuels. In parallel, the lignocellulosic seed shells possess significant potential as biomass resources for the preparation of cellulosic materials, carbonaceous materials, adsorbents, and functional fillers for composite materials. By combining biomass conversion technologies with polymer synthesis and energy-related applications, this project aims to establish an environmentally friendly and resource-efficient platform for the valorization of all major components of rubber seeds.

This project also emphasizes sustainability and circular resource utilization by promoting waste reduction and local biomass utilization in rubber plantations. Through an interdisciplinary approach integrating biomass chemistry, polymer science, and renewable energy technologies, this project seeks to contribute to the development of sustainable materials and next-generation green manufacturing systems. Ultimately, this project is expected to advance circular bioeconomy strategies and enhance the value of renewable agricultural resources through innovative material and fuel applications.



From Rubber Seed-Derived Fatty Acids to Advanced Polymer Materials: A Challenge of Vitrimer from Linoleic and Oleic Acids

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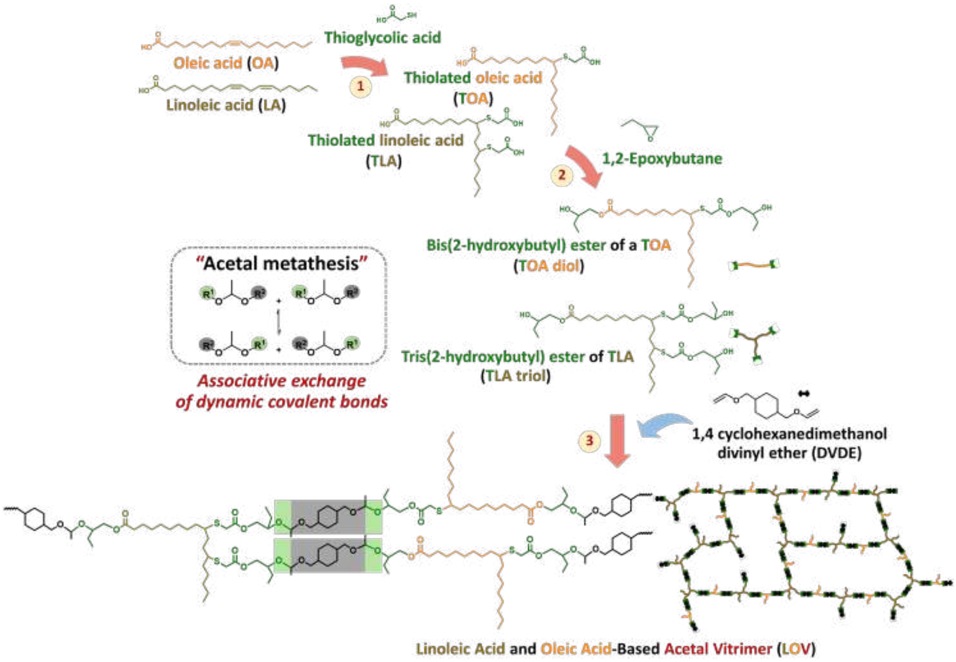
Abstract

Although rubber seeds are generally treated as agricultural waste, rubber seed oil (RSO) contains abundant saturated and unsaturated fatty acids, including palmitic, stearic, oleic (OA), linoleic (LA), and linolenic acids, making it a promising sustainable feedstock for bio-based materials. Vitrimers are polymeric materials within covalent adaptable networks (CANs) that contain dynamic covalent (DC) bonds.[1] Their thermoplastic-like reprocessability combined with thermoset-like crosslinked structures makes them promising environmentally friendly materials. Among various DC chemistries, catalyst-free acetal metathesis is particularly attractive, as it forms through reactions between hydroxyl and vinyl ether groups and undergoes acetal exchange at elevated temperatures without external catalysts.[2] From our perspective, combining fatty acid with DC networks offers a practical strategy for developing materials with tailorable structures, desirable mechanical properties, and repreocessability. In this work, OA and LA are utilized to construct vitrimeric materials (Scheme I). OA and LA are first reacted with thioglycolic acid (Step 1), followed by reaction with 1,2-epoxybutane (Step 2) to yield diol and triol monomers. Subsequent reaction with divinyl ether (Step 3) forms acetal-crosslinked OA- and LA-based vitrimers. The presentation will also cover the material performance in relation to the DC networks.

Scheme I



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Lifecycle Assessment of rubber seed oil (RSO) case study of Thailand

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Increased demand for fossil fuels leads to increased environmental impacts, both in terms of depletion of natural resources and greenhouse gas emissions, a major cause of climate change. Biodiesel form non-edible plant has been considered a suitable option for substitute of fossil fuels. Non-forest tree resources like para-rubber (Hevea brasiliensis) present dual-purpose systems capable of supplying both timber and secondary agricultural commodities like rubber seed oil (RSO). Thailand is the world's leading producer and exporter of natural rubber. Rubber seed are abundant and discarded as waste from rubber plantation in Thailand. Rubber seed biodiesel shows a significant carbon mitigation potential, to reduce greenhouse gas emissions, however, the environmental impact throughout the life cycle are important consideration. The study aims to develop an LCA framework specifically for RSO highlights the environmental advantages of shifting toward non-forest, byproduct-derived oil resources. The system boundary cover from seed collection, transportation, extraction, and refining. This system provides a robust baseline for evaluating RSO offering strategic insights for industrial supply chains and bio-polymer policy integration.

Research Keyword:
Rubber seed oil, Life Cycle Assessment (LCA), Eco-efficiency.

Vision of Future Social Implementation of Rubber Seeds and Research Exchange for Human Capacity Development

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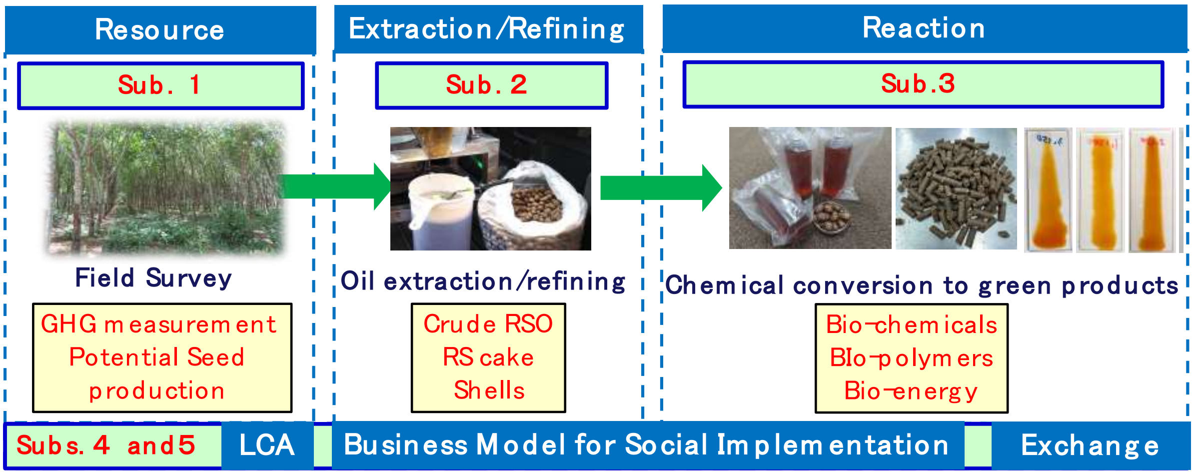
SATREPS, an international joint project between Thailand and Japan aims to develop a roadmap for the utilization of unutilized rubber seeds—a byproduct of the natural rubber industry—with the goal of providing solutions to global environmental issues, fostering research and development based on a strengthened partnership between the two countries, and ultimately achieving societal implementation. This project will totally cover from field surveys of natural rubber plantations, extraction and refining of rubber seed oil, its chemical conversion, and the demonstration of environmental impact reduction effects through life cycle assessment (LCA), thereby revealing the limitless potential of rubber seeds as a new bio-resource. We will develop individual core technologies through basic research conducted by various research institutions in Thailand and Japan and strengthen collaboration with government agencies and multiple industrial companies to facilitate societal implementation. This project also places a strong emphasis on personnel exchange and capacity building, and research exchanges between the two countries have been underway since the project's launch in 2024.

Through the implementation of this project for utilization of rubber seed, we aim to contribute to the sustainable growth of Thailand's natural rubber industry by pioneering new bio-sources as mitigation measures for global environmental issues, establishing related technologies, and facilitating their societal implementation.



Preliminary Testing for Extracting Rubber Seed Oil Using a Screw Press Extractor

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This research aimed to study the optimal conditions for extracting oil from rubber seeds using a screw press extractor. The test samples were RRIT 251 rubber seeds harvested (fallen from the tree) approximately 1-2 week prior from Loei province. The testing involved three types of rubber seeds: unhulled, dehulled, and partially hulled. These were extracted using a screw press extractor at a constant speed of 49 rpm with screw compression distances: 3.0 cm. The results showed that the optimal condition for oil extraction was using partially hulled rubber seeds, yielding the highest average oil extraction of 10.15% and the highest average production rate of 1.92 liters per hour, which was significantly higher than other types. The energy consumption during extraction was 0.21 kWh. The extracted oil contained 16.59% saturated and 83.42% unsaturated fatty acids. The temperature during extraction did not exceed 60°C, which helps preserve essential compounds in the oil. Although the screw press method yields less oil compared to solvent extraction using hexane, it offers advantages in safety, eliminates the use of hazardous chemicals, and better preserves oil quality due to lower heat and absence of chemical residues.

Research Keyword: Rubber seed, Rubber seed oil, Screw press, Cold extraction

The Role of Amphiphilic Substances in Improving the Compatibility and Performance of TPS-Based Blend Blown Films

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Thermoplastic starch (TPS) is a biobased and biodegradable material obtained from the plasticization of starch granules. It is widely used to reduce costs and enhance the biodegradability of other biodegradable thermoplastics, e.g., poly(lactic acid) (PLA) and poly(butylene succinate-*co*-butylene adipate) (PBSA), as well as to increase biobased content and reduce carbon emissions in conventional plastics, e.g., polyethylene (PE). However, blending TPS with these relatively hydrophobic polymers often leads to poor compatibility due to differences in polarity and viscosity. This presentation demonstrates the role of amphiphilic substances as compatibilizers in enhancing compatibility and improving the properties of three TPS-based polymer blend systems: (i) TPS/PLA/PBSA (40/30/30) with polyethylene glycol sorbitan monostearate (Tween 60, 0.5–2.5 wt%) [1], (ii) LLDPE/TPS (60/40) with stearic acid-grafted starch (ST-SA, 1–5 wt%) [2-3], and (iii) PLA/TPS (50/50) with oligo(lactic acid)-grafted starch (OLA-*g*-starch, 1–5 wt%) [4]. All blends were prepared via twin-screw extrusion, followed by film fabrication via blown film extrusion. The addition of 2–2.5 wt% Tween 60 significantly improved interfacial adhesion, resulting in improved mechanical, thermal, and barrier properties [1]. Similarly, 1–3 wt% ST-SA improved tensile strength, secant modulus, extensibility, UV-shielding capability, and barrier performance of LLDPE/TPS blends [2–3]. In PLA/TPS blends, 5 wt% OLA-*g*-starch markedly increased elongation at break (up to 280%) and improved barrier properties, water resistance, melt flowability, and thermal stability [4]. These results highlight the potential of amphiphilic compatibilizers to enhance interfacial compatibility and overall performance of TPS-based blends for packaging film applications.

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RETA 4th IC 2026

Poster

Session NR

Trends in Natural Rubber and their Social Impacts

Effects of Chemical Purification on Pyrolyzed Carbon Black Properties and its Performance in Natural Rubber Composites

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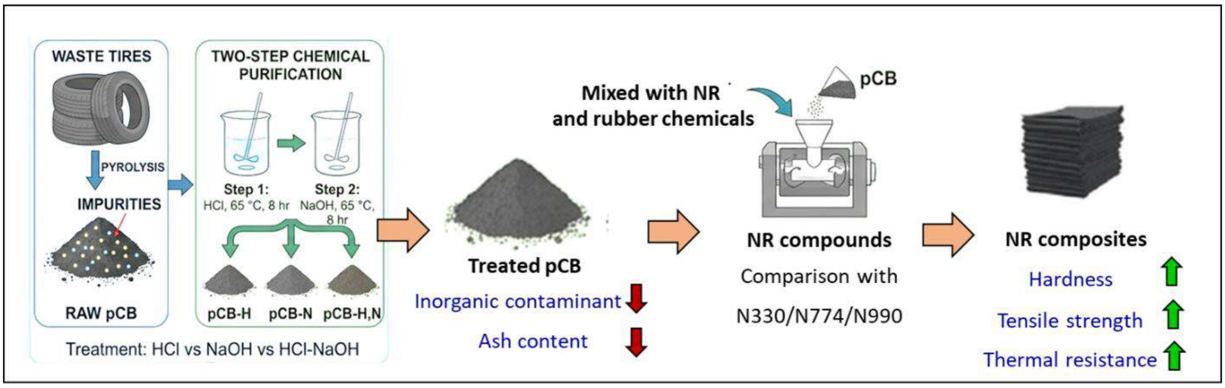
In the transition toward a circular economy, upcycling transforms end-of-life tires into high-performance resources rather than low-value waste. While pyrolysis recovers pyrolyzed carbon black (pCB), high impurity levels often limit its industrial use [1, 2]. By applying chemical purification, this raw by-product is upcycled into a sustainable functional filler that rivals commercial standards and reduces the carbon footprint of rubber manufacturing [2, 3].

This study investigated the enhancement of pyrolyzed carbon black (pCB) derived from waste tire pyrolysis through a two-step chemical purification process. To improve purity and reduce inorganic impurities, pCB was treated with hydrochloric acid (HCl) and sodium hydroxide (NaOH) at 65 °C for 8 h. The purification treatments were categorized into three groups: pCB-H (HCl), pCB-N (NaOH), and pCB-H,N (combined HCl and NaOH). Characterization results from ICP-OES, SEM-EDS, TGA, and FT-IR confirmed that the combined HCl–NaOH treatment (pCB-H,N) was the most effective method. This treatment successfully removed metallic and inorganic contaminants, resulting in higher carbon content and superior thermal stability compared to single-agent treatments. The purified pCB samples were incorporated into natural rubber (NR) at a loading of 40 phr and compared with commercial CB grades (N330, N774, and N990). The experimental results demonstrated that rubber composites containing pCB-H and pCB-H,N exhibited significantly enhanced mechanical properties, including higher tensile strength and hardness, particularly over CB N774 and N990. Furthermore, these composites showed improved resistance to thermal degradation and fluids. Notably, the properties of the developed rubber compounds complied with the Thai Industrial Standard (TIS 237–2552) for water pipe rubber seals, suggesting that purified pCB is a viable sustainable alternative to commercial fillers.



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Research Keywords: Rubber composites, Filler, Pyrolyzed carbon black, Purification

Effects of Processing Conditions on Yellow Discoloration of Natural Rubber Latex Foam

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Abstract

Yellowing of natural rubber (NR) latex foam remains a persistent challenge in latex product manufacturing due to its adverse impact on product appearance and market acceptance. Processing conditions and chemical additives are known to significantly influence discoloration behavior; however, their combined effects on foam yellowness are not yet fully understood. This study investigated the effects of processing parameters on the yellowness index (YI) of NR latex foam, with particular emphasis on latex clone type, accelerator system, drying condition, and leaching treatment. Latex foam samples were fabricated via the Dunlop process by varying latex clone type, accelerator system, drying temperature, and leaching treatment. Foam discoloration was quantitatively assessed using yellowness index measurements according to ASTM E313.

The results showed that both latex source and processing conditions significantly affected foam discoloration. Foams prepared from the RRIM600 clone exhibited lower YI values than those from RRIT251. In terms of vulcanization chemistry, the ZDEC/ZMBT accelerator system produced lower yellowness compared with thiuram-based systems. Increasing the number of leaching cycles effectively reduced YI, likely due to the removal of residual chemicals and impurities from the foam matrix. In contrast, higher drying temperatures intensified foam yellowing, whereas drying at 70 °C for 16 h resulted in the lowest YI. In addition, copper ion contamination was found to further accelerate discoloration of the latex foams. The results contribute to a better understanding of processing-induced discoloration in NR latex foam and provide practical guidance for improving the appearance quality of latex foam products.

Sustainable Photocatalytic Degradation of Natural Rubber Latex for Functionalized Low Molecular Weight Rubber (FLNR) Production

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Abstract

Natural rubber (NR) possesses excellent mechanical properties but limited chemical reactivity due to the absence of polar functional groups. In this study, functionalized low molecular weight natural rubber (FLNR) was prepared via photocatalytic degradation of deproteinized natural rubber (DPNR) latex using TiO_2-coated hollow glass beads (TiO_2-HGBs) under UVA irradiation in the presence of hydrogen peroxide (H_2O_2). The TiO_2-HGB system was developed to overcome the recovery and reusability limitations of conventional TiO_2 powder photocatalysts.

The degradation process was carried out using 30 phr H_2O_2 and 25 TiO_2-HGBs under 1000 W UVA irradiation for 30 min. Under the optimized condition, the number-average molecular weight (Mn) of DPNR decreased from 9.48×10^5 to 0.28×10^5 Da, while the weight-average molecular weight (Mw) decreased to 1.43×10^5 Da. FTIR and NMR analyses confirmed the formation of hydroxyl, carbonyl, and epoxide groups on the degraded rubber chains. The TiO_2-HGB photocatalyst could be reused effectively for at least seven cycles while maintaining degradation efficiency.

Compared with conventional TiO_2 powder systems, TiO_2-HGBs provide easier catalyst separation and improved reusability. The resulting FLNR showed potential for applications as reactive modifiers, compatibilizers, adhesives, and polyurethane precursors. This work demonstrates a practical and environmentally friendly approach for producing value-added functional rubber materials under mild conditions [1–3].

Keyword: Natural rubber, Functionalized Low Molecular-Weight Natural Rubber, Titanium Oxide (TiO_2), hollow-grass bead (HGB), Photochemical reaction

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Preparation of Low-Allergen Natural Rubber via Saponification and Deproteinization Processes

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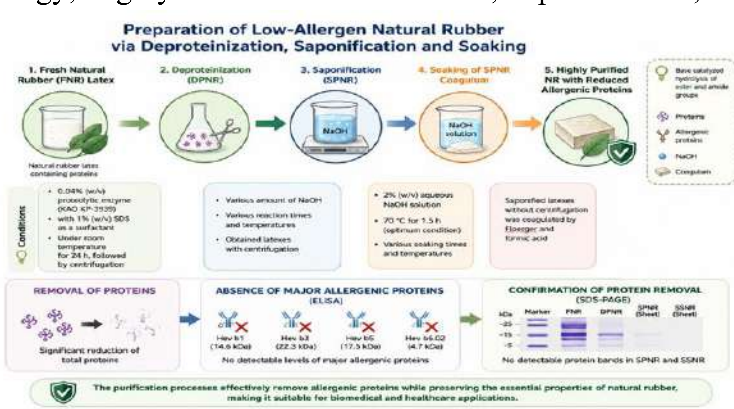
Abstract

Latex allergy associated with residual proteins in natural rubber (NR) products remains a significant challenge in biomedical and healthcare applications [1]. Strategies capable of efficiently removing allergenic proteins while preserving the desirable properties of NR are therefore highly desirable. In this work, saponification combined with deproteinization was employed to reduce residual proteins and allergenic components in NR latex. The effects of NaOH concentration, treatment temperature, and reaction time on purification efficiency were systematically evaluated. Residual proteins and allergenic components in the purified rubber samples were analyzed using protein quantification assays, ELISA, and SDS-PAGE analysis [1-2]. The optimized saponification condition was achieved using 1% (w/v) NaOH at 70 °C for 3 h, resulting in SPNR with nitrogen content below 0.02%. Additional soaking treatment in 2% NaOH at 70°C for 1.5h further reduced residual nitrogen and extractable proteins. Although small amounts of total extractable proteins were still detected by the Lowry assay, ELISA analysis confirmed the absence of major allergenic proteins, indicating that allergenic components were effectively eliminated despite residuals non-allergenic proteins remaining in the purified NR. ELISA analysis targeting major allergenic proteins (Hev b1, Hev b3, Hev b5, Hev b6.02) showed no detectable allergenic proteins after soaking treatment. SDS-PAGE analysis further confirmed significant removal of protein components after purification. The treatment also preserved the desirable characteristics of NR, demonstrating that saponification combined with deproteinization is an effective approach for producing highly purified NR with substantially reduced allergenic proteins. The Purification process preserved the essential characteristics of NR, indicating its suitability for further biomedical and healthcare applications.

Keywords: Latex allergy, Highly Purified Natural Rubber, Saponification, Deproteinization



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Low-Temperature Stable Puncture Sealing Agents Based on Modified Natural Rubber Latex Systems

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Conventional puncture sealing agents (PSAs) often exhibit poor performance at low temperatures due to freezing and phase instability, leading to reduced sealing efficiency and limited reliability in clod environments. Developing PSAs with improved freeze resistance and stable rheological behaviour therefore remains an important challenge for tire sealing applications. In this study, low-temperature stable PSAs were developed from modified natural rubber latex systems through formulation optimization. Deproteinized natural rubber (DPNR) latex and saponified natural rubber (SPNR) latex were formulated with surfactants, tackifying resin, and anti-freezing additives to prepare a series of PSA formulations. The physicochemical and rheological properties of the formulations, including particle size, zeta potential, viscosity, and mechanical stability, were evaluated. The results showed that DPNR-based formulations remained in a stable liquid state at −20 °C, indicating superior freeze resistance compared with SPNR-based systems. Among the investigated formulations, Formula 5 (40:20:20) exhibited the best overall stability across a wide temperature range. In addition, DPNR-based PSAs showed lower viscosity than SPNR-based formulations while maintaining viscosities below 1000 cP, which is suitable for puncture sealing applications. Overall, the results demonstrate that modified natural rubber latex systems, particularly DPNR-based formulations, are promising candidates for low-temperature puncture sealing applications requiring stable flowability and freeze resistance.

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Hybrid Reinforcement of Natural Rubber Tread Compounds Using Silane-Modified Spent Coffee Grounds and Carbon Black for Sustainable Truck Tire

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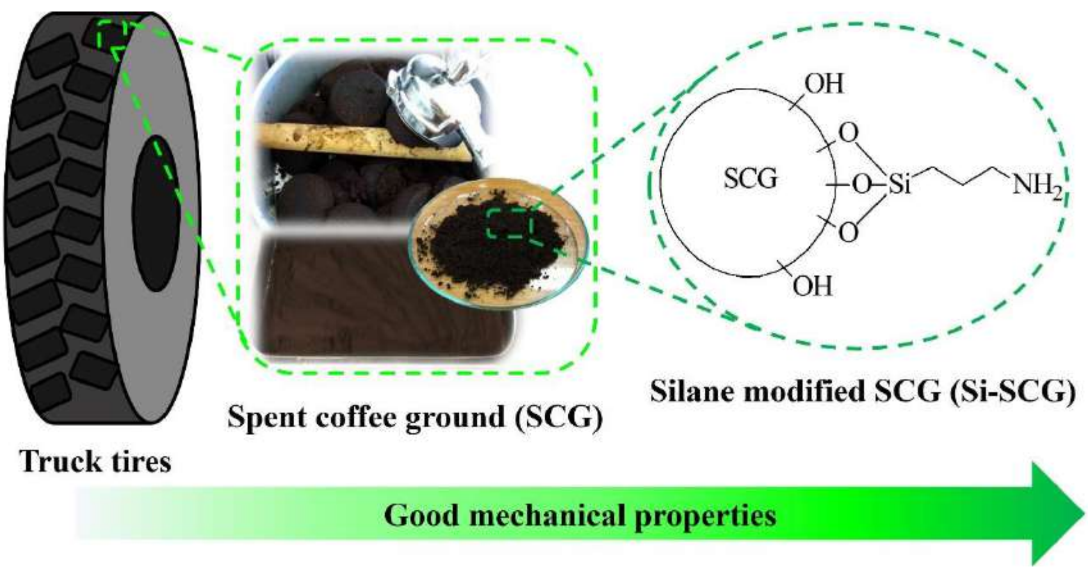
Abstract

The increasing demand for sustainable materials in the tire industry has driven the exploration of renewable and waste-derived fillers as alternatives to conventional reinforcing agents. In this study, hybrid reinforcement systems for natural rubber (NR) tread compounds were developed using spent coffee grounds modified with a silane coupling agent (Si-SCG) in combination with carbon black (CB). NR compounds containing various ratios of Si-SCG and CB were prepared using a two-roll mill machine, followed by vulcanization using a conventional sulfur curing system. The total loading of the hybrid filler system was maintained at 60 phr. The effects of hybrid filler composition on curing characteristics, mechanical properties, abrasion resistance, and heat buildup were systematically evaluated. The results showed that scorch time, cure time, Mooney viscosity, tensile strength, and elongation at break decreased with increasing Si-SCG loading, whereas the 100% modulus, hardness, and abrasion loss increased. These trends can be attributed to the reduction in carbon black (CB) content as it was progressively replaced by Si-SCG. However, the reduction in heat buildup suggests enhanced energy dissipation within the hybrid filler system, likely resulting from the lower CB content together with the improved dispersion and interfacial interaction of Si-SCG within the NR matrix. This work demonstrates the potential of silane-modified SCG as a sustainable filler in combination with CB for truck tire tread compounds, thereby reducing reliance on petroleum-based materials while maintaining acceptable performance.



Surface Modification of Natural Rubber Latex Gloves via Epoxidation and Hydroxylation for Powder-Free Applications

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The development of powder-free natural rubber latex (NRL) gloves has attracted significant attention due to increasing concerns regarding powder-induced allergies and the limitations of conventional chlorination processes. Alternative surface modification strategies capable of improving glove surface properties without compromising mechanical performance are therefore highly desirable. In this study, surface modification via epoxidation and hydroxylation was investigated as an alternative approach for producing powder-free NRL gloves. The modification process involved the formation of epoxide groups on the polyisoprene surface, followed by ring-opening hydroxylation to enhance surface polarity and reduce tackiness. The effects of performic acid concentration and reaction time on surface modification efficiency were systematically evaluated. The modified glove surfaces were characterized using contact angle measurement, tensile testing, and ATR-FTIR spectroscopy to evaluate changes in surface polarity, mechanical properties, and chemical functionality. The optimum surface modification condition was obtained using 5% (w/v) performic acid with a reaction time of 50–70 min. Contact angle measurements showed that the modified glove surfaces achieved surface polarity comparable to that of conventionally chlorinated gloves. ATR-FTIR analysis confirmed the formation of epoxide and hydroxyl functional groups on the glove surface, while tensile testing indicated that the modification process did not adversely affect the mechanical properties of the gloves. These results demonstrate that controlled epoxidation and hydroxylation provide an effective alternative surface treatment for the production of high-performance powder-free NRL gloves.

Keywords: Natural rubber latex, surface modification, epoxidation, hydroxylation, powder-free gloves.

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Poster

Session SR

Vital Roles of Synthetic Rubber and Elastomers

Eco-friendly Sprayable Mulch Film Derived from Cassava Starch and Natural Rubber Latex Composites

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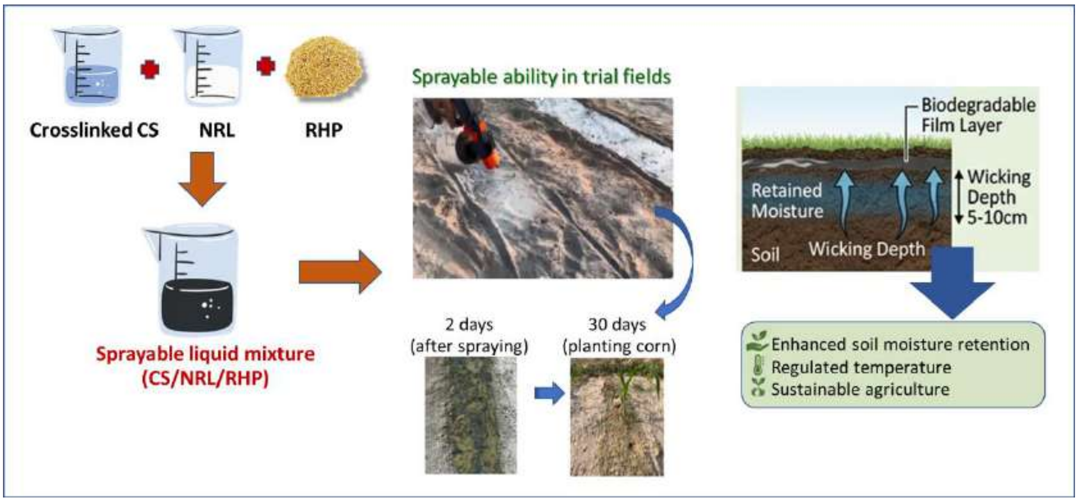
Unlike traditional polyethylene, liquid mulch film offers a sustainable alternative by forming a biodegradable barrier directly on the soil. This sprayable technology eliminates plastic waste and labor-intensive removal, supporting a circular economy through natural decomposition [1, 2]. Liquid mulch film is an innovative biodegradable alternative to traditional plastic. This study developed an eco-friendly liquid mulch film that can be sprayed directly onto the soil [3]. The film was made by mixing the crosslinked cassava starch with potassium persulfate (XCS) and natural rubber latex (NRL) with rice husk powder (RHP) and a small amount of glycerol for flexibility.

The base mixture was prepared using gelatinized XCS and NRL at weight ratios of 100/0, 90/10, 80/20, and 70/30 %wt/wt, with 2.5 %wt glycerol added as a plasticizer. We further investigated the effect of RHP content (0-20 %wt) on the resulting film properties. Results indicated that increasing the NRL content reduced the tensile modulus but increased tensile strength, attributed to the elasticity of natural rubber and the intrinsic structural linkages between XCS and NR. The optimum XCS/NRL ratio was identified as 80/20 %wt/wt. While the addition of RHP increased the mixture viscosity, tensile modulus, and biodegradability (via soil burial tests), it led to a decrease in tensile strength. Field trials demonstrated that the 80/20 XCS/NRL formulation with 10 %wt RHP possessing a modulus of 0.25 MPa and a tensile strength of 2.09 MPa offered superior performance. This formulation achieved 40% degradation after 60 days of soil burial and exhibited the highest wicking depth and moisture/temperature retention capabilities. The experimental results of the sprayable mulch film indicated that after 30 days, the filmed areas remained weed-free, whereas the untreated areas experienced weed growth. Furthermore, it was observed that the mulch film enhanced the growth of corn plants compared to the control group.



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Research Keywords: Natural rubber latex, Cassava Starch, Sprayable mulch film, Rice husk powder, Biodegradation

From Permanent to Dynamic Crosslinked Networks: The Way to Unlock the Potential of Bio-Based Multi-Arm Vitrimeric Elastomers

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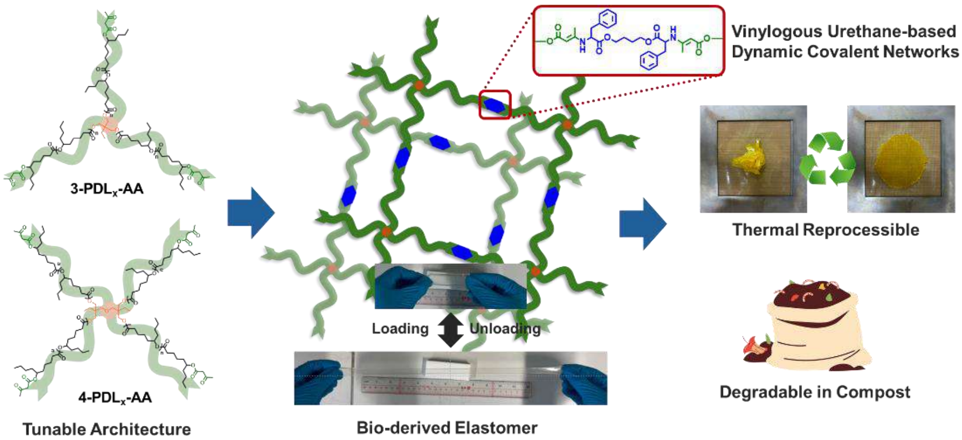
Developing elastomers that simultaneously combine mechanical robustness, reprocessability, controlled degradability, and sustainable sourcing remains a significant challenge in polymer materials science. In this work, a bio-based vitrimeric elastomer is constructed using star-shaped poly(ε-decalactone) (PDL) and a bio-derived crosslinker through dynamic vinylogous urethane chemistry. Well-defined three- and four-arm PDL precursors with tunable chain lengths are synthesized and subsequently functionalized with acetoacetate groups, enabling catalyst-free associative transamination reactions to form covalent adaptable networks.

The resulting elastomers exhibit low glass transition temperatures (-49 to -39 °C), stable rubbery plateaus, and outstanding extensibility, achieving elongation at break up to 2100%. By varying arm number and chain length, the crosslink density and network topology can be systematically controlled, allowing precise tuning of stiffness, toughness, and bond exchange dynamics. Stress relaxation studies reveal Arrhenius-type behavior with topology-freezing temperatures near ambient conditions, confirming the vitrimeric nature and enabling thermal reprocessability. After multiple reprocessing cycles, the materials retain approximately 75% of their initial mechanical performance.

Under industrial composting conditions (ASTM D5338), the elastomers undergo significant molecular weight reduction (up to 90%) and surface erosion, with degradation behavior strongly influenced by crosslink density. This study demonstrates an effective molecular design strategy for sustainable elastomers by integrating renewable building blocks, dynamic covalent networks, and degradable polymer backbones, providing a promising pathway toward recyclable and environmentally responsive soft materials.

Scheme I



RE TA 4th IC 2026

Poster

Session GM

Unlock Potential of Green Materials

Star-Shaped Poly(lactic acid) and Poly(butylene succinate): Tailoring Biodegradable Polymers via Architecture Control

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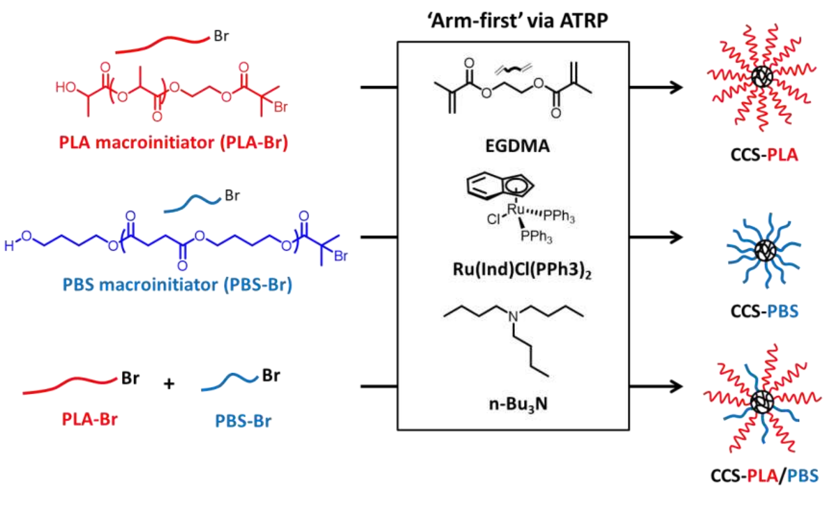
Abstract

Poly(lactic acid) (PLA) and poly(butylene succinate) (PBS) are widely recognized bio-based and biodegradable polyesters for sustainable material development. PLA, derived from renewable resources, exhibits high strength and transparency but suffers from brittleness, while PBS provides flexibility and toughness with good biodegradability. Combining PLA and PBS is a promising strategy to balance performance and biodegradability; however, achieving compatibility and controlled property integration remains challenging.

In this work, star-shaped polymers with well-defined architectures are explored to effectively integrate and tailor their properties (Scheme I).[1] Core-crosslinked star PLA (CCS-PLA) was synthesized via an arm-first approach by polymerizing bromo-terminated PLA macroinitiators with divinyl crosslinkers, yielding polymeric core-shell nanoparticles. When incorporated into PLA matrices, CCS-PLA induces minimal shifts in glass transition (T_g), cold crystallization (T_{cc}), and melting temperature (T_m), suggesting improved miscibility and a plasticizing effect that mitigates the intrinsic brittleness of PLA. To further expand functionality, miktoarm star copolymers (CCS-PLA/PBS) were developed by integrating PLA and PBS chains within a single core-crosslinked structure. The distinct thermal transitions of PLA and PBS initiate tunable thermo-responsive behavior through compositional variation. This architecture promotes synergistic property integration while maintaining biodegradability. Within the framework of circular materials, this study demonstrates a strategy to design high-performance, biodegradable polymers. Star-shaped architectures combined with PLA and PBS provide a promising platform for sustainable high-performance plastics.

Scheme I



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Effect of Stretching on Crystallization and Oligomer Distribution in Antistatic Biodegradable PLA Films

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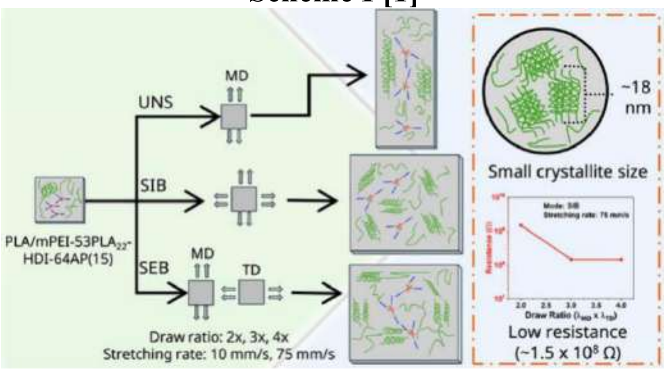
The development of antistatic biodegradable polymers such as polylactic acid (PLA) is hindered by its high electrical resistance. To address this, a branched conductive PLA oligomer terminated with an aniline pentamer (mPEI-PLA-HDI-AP) was incorporated at 15 wt% into PLA films. The effects of uniaxial (UNS), simultaneous biaxial (SIB), and sequential biaxial (SEB) stretching on chain alignment and electrical conductivity were systematically studied.

Higher stretching rates (75 mm/s) and larger draw ratios (up to 4×) significantly enhanced crystallization, particularly in SIB and SEB processes. These conditions produced small crystallites (<20 nm) and low cold-crystallization enthalpies (<5 J/g), as confirmed by WAXD and DSC. As a result, surface electrical resistance decreased dramatically to as low as 10^8 Ω.

In contrast, annealed films with similar crystallinity showed no improvement in resistivity, indicating that crystallinity alone is insufficient. Instead, reduced resistance arises from the combined effects of crystalline organization and improved dispersion and orientation of the conductive oligomer, achieved through controlled stretching. Overall, this approach reduces film resistance from ~10^{10} Ω to 10^8 Ω, demonstrating the potential of stretched PLA films with conductive oligomers for antistatic packaging applications (**Scheme 1**).

Scheme I [1]



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Unlocking the Potential of Chitosan-Based Molecular Blocks for Drug-Free Cancer Cell Disruption

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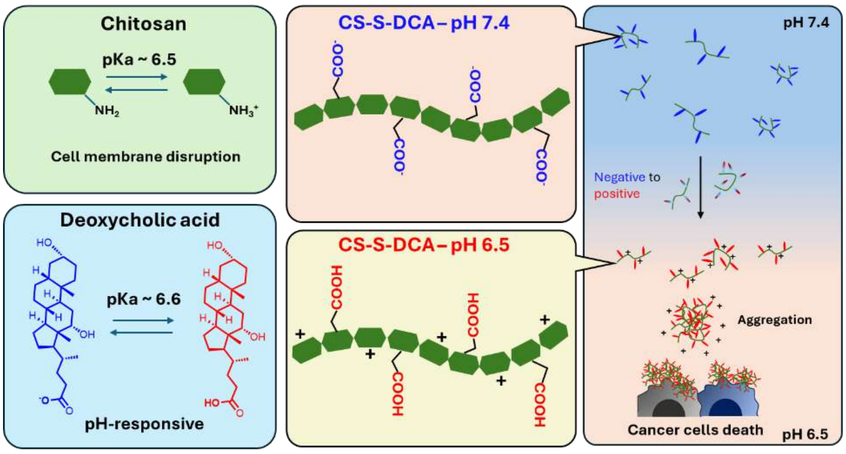
Abstract

Molecular blocks (MB) are reported as drug-free cancer pharmacotherapies based on the performance of polymeric nanoparticles dispersed in blood vessels but aggregated in the cancer cell microenvironment (pH = 6.3–6.5) for cell membrane disruption. The present work proposes the conjugation of deoxycholic acid (DCA) and AS onto chitosan (CS) to form a polymeric MB. The pH responsiveness of DCA and CS enables concerted performance related to cancer cell membrane disruption, with DCA aggregation and cancer cell membrane adhesion through ionic interactions with CS. By simply applying water-based CS succinate (CS-S), the conjugation of sodium deoxycholate (DCA-Na) to obtain CS-S-DCA. CS-S-DCA shows significant aggregation at pH 6.2, while the size is reduced by half at pH 7.4. This leads to cytotoxicity in cancer cells, such as MiaPaCa-2, A-549, and HT-29 cells, but is compatible with normal cells, including NHDF cells. The study demonstrates the concerted pH-responsive performance of the polymeric MB and the efficacy of AS against cancer cell surfaces, including its potential for chemotherapeutic treatment.

Scheme I



Sustainable Bio-based Filler from Macadamia Carbon for Natural Rubber Composites: A Comparative Study with Carbon

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Abstract

This study evaluates the potential of Macadamia carbon (MC), a sustainable bio-based filler derived from agricultural waste, as an alternative to conventional carbon black (N330) in natural rubber (NR) composites. MC powders were processed through sequential ball milling and high-speed milling to achieve fine particle sizes down to approximately 0.7 µm. NR composites filled with MC and N330 were prepared and systematically characterized in terms of cure behavior, viscosity, mechanical properties, and thermal performance. The results revealed that both particle size and the intrinsic composition of MC, particularly the presence of metal elements such as manganese and copper, significantly influenced curing kinetics. MC-filled systems exhibited longer scorch and cure times compared to N330-filled composites. Mechanical evaluation showed that reducing MC particle size improved tensile strength and modulus compared to untreated MC. However, the reinforcing efficiency and heat build-up resistance of MC composites remained lower than those of N330 systems, primarily due to weaker filler–rubber interactions and reduced compatibility. Despite these limitations, MC demonstrates strong potential as a renewable and environmentally friendly filler. This study highlights the importance of surface modification and compatibility enhancement to further improve performance. The findings contribute to the development of sustainable rubber composites and support the transition toward greener materials in the rubber industry.

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Development of Dielectric Composite Materials via Transition Metal-Benzoxazine Complexes for Stereolithography 3D Printing

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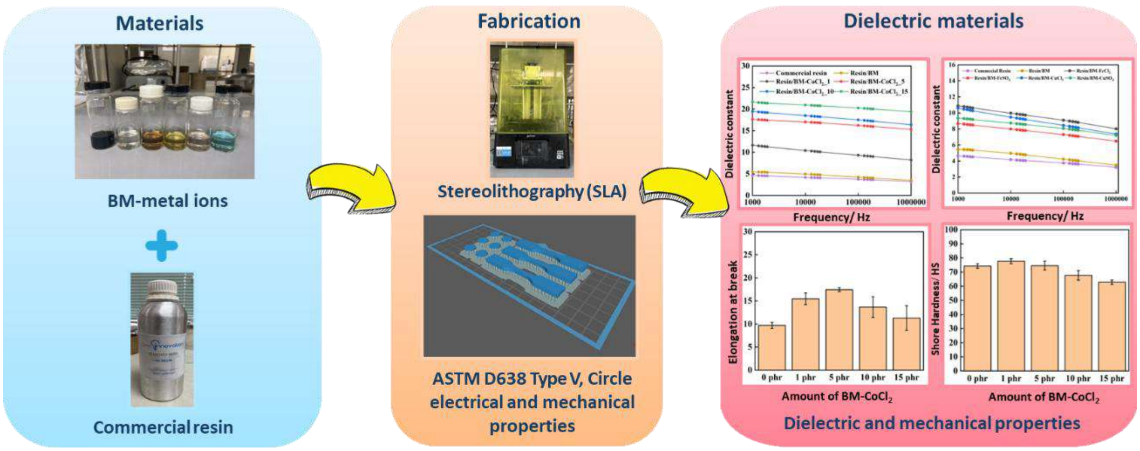
Abstract

This research explores the development of advanced dielectric materials by incorporating transition metal complexes of benzoxazine as functional fillers into commercial resins using Stereolithography (SLA) 3D printing. Initially, a benzoxazine monomer (BM) was synthesized from bisphenol A, cyclohexylamine, and paraformaldehyde via Mannich reaction. This monomer reacted with cobalt chloride ($CoCl_2$) at a 4:1 molar ratio to form a BM-complex, as confirmed by UV-Vis and TGA analysis. The incorporation of only 1 phr of BM-$CoCl_2$ into the resin resulted in a dielectric constant 2.4 times higher than that of the neat commercial resin. Furthermore, increasing the concentration (5–15 phr) led to continued enhancement of dielectric values while maintaining exceptionally low loss tangent values. Beyond electrical performance, the additive improved the elongation of the resin, and the resulting waste product (incinerated Co_3O_4) remains effective for secondary use as a catalyst [1].

Building upon these results, the study investigated the influence of different metal ions (Fe^{2+} and Cu^{2+}) and their respective counter ions (chloride and sulfate). Composites containing 1 phr of these complexes exhibited significant dielectric constants ranging from 9 to 11, compared to 4.5 for the base resin. The research identified that complexation kinetics and the final dielectric tuning are heavily dependent on the choice of both the metal center and the counter ion. These findings demonstrate a versatile strategy for customizing the dielectric and mechanical properties of 3D printed components for specialized industrial applications[2].



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Poster

Session CC

JSPS Core-to-Core Program

Selective Hydrogenolysis of LDPE to Valuable Chemicals over La_2O_3 Doped CeO_2 Ru-based Catalysts

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The production and consumption of plastics have led to significant environmental concerns over the past few decades. Hydrogenolysis of the C-C bonds in polyolefins offers a viable option for the transformation of polyolefins into valuable saturated hydrocarbons. Our laboratory has reported that Ru-based catalysts (Ru/CeO_2 and Ru/ZrO_2) are effective heterogeneous catalysts for the hydrogenolysis of polyolefins to valuable chemicals such as liquid (C5-21) and wax (C≥22) [1-4]. However, inexpensive gas products (C1-C4) were formed in ~10% selectivity. Therefore, we aim to develope Ru-based catalysts that suppress gas production to achieve high yields of valuable chemicals.

Ru/La_2O_3(x)-CeO_2 (Ru: 5 wt%, x = loading amounts of La_2O_3) catalysts were prepared by impregnation method. We investigated the effect of adding lanthanide oxides into the CeO_2 of Ru/CeO_2 in the hydrogenolysis of LDPE. The La_2O_3-doped CeO_2-supported Ru catalyst exhibited high activity and the lowest gas selectivity. We examined the effect of La_2O_3 loading amounts in Ru/La_2O_3(x)-CeO_2 catalysts (Fig. 1). As the La_2O_3 loading increased from 0 to 9 wt%, the catalyst activity gradually decreased, while the selectivity of gas products showed a concurrent decline. A further increase beyond 9 wt% led to a significant reduction in the catalytic performance (Fig. 1a, b). Catalyst characterizations revealed that the doping of La_2O_3 to CeO_2 formed strong base sites, which interacted with Ru metals to suppress the aggregation of Ru metal particles. Smaller Ru nanoparticles favored the production of valuable chemicals over gas products by effectively suppressing excessive C-C hydrogenolysis.

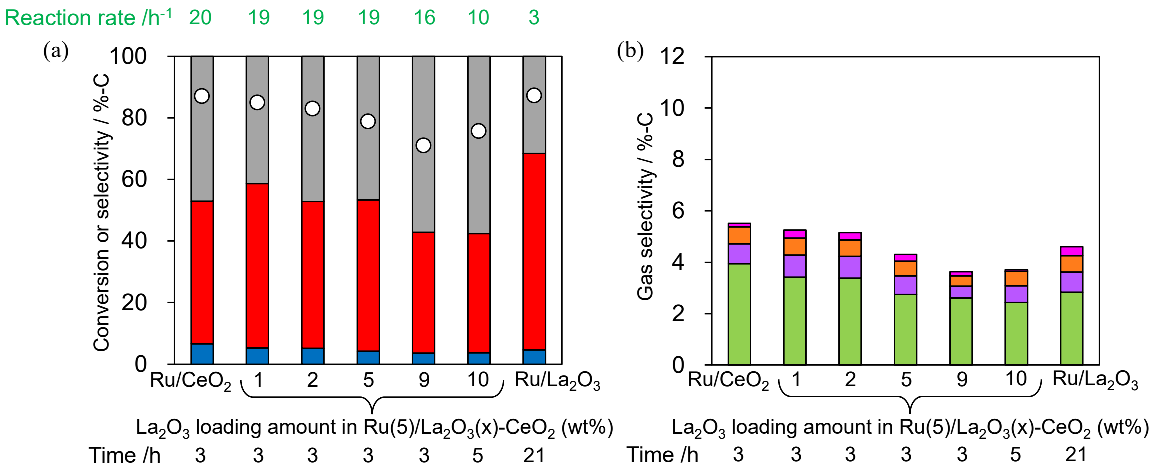

Figure 1 Hydrogenolysis of LDPE over Ru/La_2O_3(x)-CeO_2 catalysts. Reaction conditions: catalyst 50 mg, LDPE 3.4 g, 6 MPa H_2, 513 K, 3-21 h.

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Amphiphilic Block Copolymer-Based Photocurable Hydrogels with Tunable Mechanical Properties and Environmental Responsiveness

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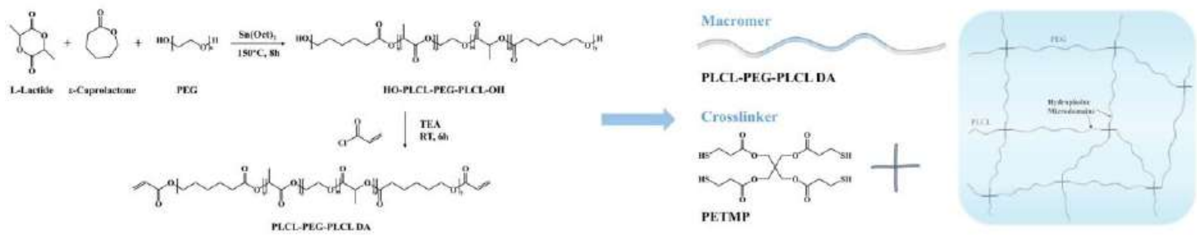
Abstract

Amphiphilic hydrogels that combine mechanical robustness, environmental responsiveness, and degradability are highly attractive for advanced soft material applications. In this work, a pentaerythritol tetrakis(3-mercaptopropionate) (PETMP)-assisted thiol-ene photocrosslinking strategy was developed to fabricate photocurable hydrogels based on poly(l-lactide-co-ε-caprolactone)-b-poly(ethylene glycol)-b-poly(l-lactide-co-ε-caprolactone) (PLCL-PEG-PLCL) diacrylate macromers in water/ethanol cosolvent systems. The cosolvent approach enabled homogeneous precursor formation, while the tetrafunctional thiol crosslinker PETMP promoted efficient network construction and improved structural integrity.

By varying the hydrophobic block length and solvent composition, the resulting hydrogels exhibited systematically tunable transparency, solvent/water content, shrinkage-swelling behavior, and compressive mechanical properties. Solvent exchange from water/ethanol to pure water induced pronounced yet reversible shrinkage, accompanied by network densification and mechanical reinforcement. The hydrogels also showed reversible temperature-dependent deswelling behavior, attributed to hydrophobic microdomain formation within the amphiphilic network. In addition, the ester-containing networks displayed pH-dependent hydrolytic degradation, with accelerated swelling and structural collapse under alkaline conditions. The amphiphilic structure further enabled efficient loading of hydrophobic molecules from aqueous media and sustained release in water, highlighting the functional role of internal hydrophobic domains.

This study provides a versatile design strategy for constructing mechanically adaptable, responsive, and degradable amphiphilic hydrogels for future biomedical and soft material applications.

Scheme I. Synthesis of Diacrylate Macromers and Formation of Networks



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Upcycling of Poly(ε-caprolactone) into Azepane via Pt/TiO_2-Catalyzed Reductive Ammonolysis

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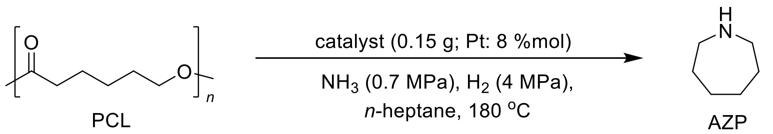
Abstract

Chemical recycling and upcycling offer promising routes to reduce plastic waste, yet both often require high energy and show limited selectivity. Poly(ε-caprolactone) (PCL), widely used in medicine, food packaging, and 3D printing, has grown rapidly in recent years, yet methods for its chemical upcycling are still limited. In this work, we demonstrate the upcycling of PCL into azepane (AZP) via reductive ammonolysis over Pt/TiO_2. AZP represents a nitrogen-containing heterocycle with antidiabetic, anticancer, and antiviral potential.

The reaction was conducted at 180 °C under 4.0 MPa H_2 and 0.7 MPa NH_3 (Table). Pt/TiO_2 afforded 18 % of AZP after 6 h (entry 1), which increased to 75 % after 25 h (entry 2). The catalyst was reusable without significant loss of activity (entry 3). In contrast, bare TiO_2 exhibits no catalytic activity (entry 4), highlighting the crucial cooperation between the Pt and TiO_2 in the system. Detailed control experiments and structural characterization confirm that the cooperative roles of Pt nanoparticles with TiO_2 acidic sites are crucial for AZP formation. The catalytic performance of Pt/TiO_2, the roles of Pt and TiO_2, and the proposed reaction pathway will be discussed in the presentation.[1]

Table. PCL upcycling with NH_3 to AZP over various supported metal catalysts[a]



Entry	Catalyst	Time [h]	AZP yield [%][b]
1	Pt/TiO_2	6	18
2	Pt/TiO_2	25	75
3	Pt/TiO_2 (Reuse of entry 2)	25	71
4	TiO_2	6	0

[a] Reaction conditions: PCL (0.5 mmol eq. of monomer unit). [b] Yield was determined by GC-FID and was calculated based on the initial PCL monomer unit.

Reference

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High-Purity Lignin Recovery from Oil Palm Residues via Ternary Natural Deep Eutectic Solvents with High-Pressure Conditions

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Unlocking the potential of green materials requires a fundamental shift in how industrial byproducts are transformed into high-value resources. While lignin is a premier renewable precursor for bioplastics and advanced chemicals,[1] its extraction from complex agricultural residues such as Empty Fruit Bunch (EFB) remains a significant technical hurdle. Traditional methods often rely on harsh, energy-intensive chemicals that degrade lignin structure and harm the ecosystem. This study addresses these challenges by developing a sustainable extraction process using ternary Natural Deep Eutectic Solvents (ternary NADES) under high-pressure autoclave conditions [2]. The use of biodegradable solvents combined with high pressure enhances solvent penetration into the biomass matrix, enabling selective lignin extraction while preserving structural integrity. Key parameters including solvent ratio, temperature, water content, and extraction time were systematically investigated using a one-factor-at-a-time (OFAT) approach. The optimal conditions (160 °C, solvent ratio 1:1:2, 20% water content, and 4-hour extraction time) produced lignin recovery yield of approximately 54%. Among the parameters studied, solvent ratio achieved the highest individual lignin recovery yield of 90.38%, followed by temperature (55.96%) and water content (51.96%), while prolonged extraction time reduced the yield to 25.07%, suggesting lignin condensation or redeposition. FTIR analysis confirmed preservation of characteristic lignin functional groups, while SEM images showed disruption and increased porosity of treated EFB fibers. Furthermore, ternary NADES demonstrated good recyclability with solvent recovery efficiency of approximately 85%. Overall, this study highlights a green and efficient strategy for valorizing palm oil waste, supporting the transition toward a sustainable bioeconomy.

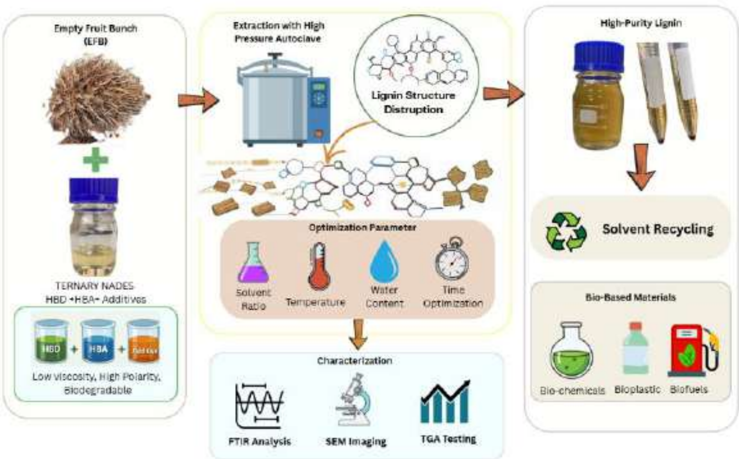

Figure 1 Schematic illustration of lignin extraction from EFB using ternary NADES under high-pressure autoclave conditions.

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Research Keyword (3-5 keywords use commas to separate each word):
Ternary NADES, Lignin Extraction, Biomass, Green Solvents, Biorefinery.

Anisotropic Hydrogel Reinforced with Polydopamine-Coated Cellulose Nanocrystals for Dual-Responsive Actuation

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Abstract

Nature-inspired stimuli-responsive hydrogels hold great potential for advanced applications in soft robotics, tissue engineering, and bionic systems. Poly(*N*-isopropylacrylamide) (PNIPAAm)-based hydrogels are a representative class, known for their thermoresponsive volume phase transition[1]. However, their use is limited by poor mechanical strength and restricted actuation modes. Polydopamine (PDA) can be easily deposited on various substrates, including cellulose nanocrystals (CNCs), through the self-polymerization of dopamine. PDA coatings allow further functionalization and provide photothermal properties, making them attractive for designing responsive hydrogel systems. Here, we report anisotropic PNIPAAm-based hydrogel actuators incorporating polydopamine-coated cellulose nanocrystals (PDACNCs) for simultaneous photothermal conversion and mechanical reinforcement combined with a two-step metal ion cross-linking strategy targeting carboxylate groups in the network. Uniform Al^{3+} cross-linking enhanced the stiffness and toughness of the hydrogels, while controlled Fe^{3+} diffusion produced gradients of cross-linking density, enabling anisotropic swelling and deswelling. Optimization of the Al^{3+} and PDACNC contents yielded the best balance between mechanical robustness and actuation speed. Under thermal stimulation, the actuators achieved bending angles of up to 280° within 0.3 min, whereas higher Al^{3+} or PDACNC levels slowed the response and reduced deformation. Patterned Fe^{3+} diffusion enabled diverse programmable deformation modes including bending, twisting, and folding. Moreover, the photothermal effect of PDACNCs facilitated rapid, remote actuation under near-infrared irradiation. This work presents a versatile design platform for dual-responsive hydrogel actuators with tunable performance and complex, programmable shape transformations[2].

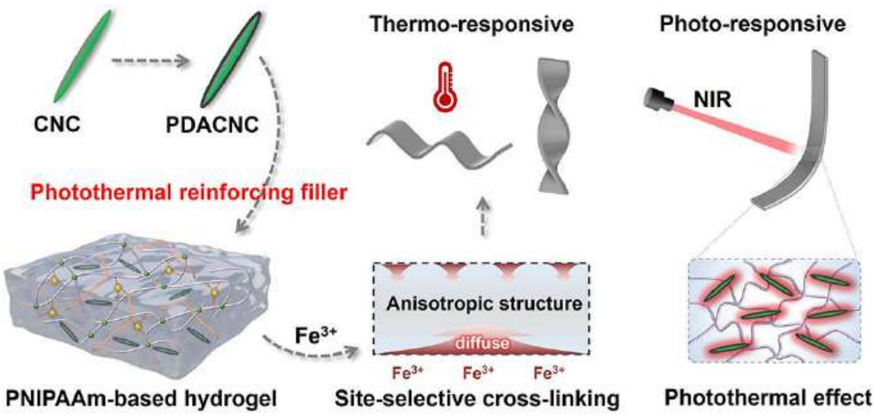

Figure 1. Schematic illustration of PDACNC-reinforced PNIPAAm hydrogels with anisotropic cross-linking, enabling near-infrared light-driven and thermo-programmable actuation.

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Sustainable UV-Curable Nanocomposite Coatings Based on ZnO–Ag Nanoparticles: Recent Advances in Antimicrobial and Self-Cleaning Application

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Abstract

Microbial proliferation and surface organic contamination in harsh environments demand the engineering of smart protective coatings. Radiation-curing (UV-curing) technology represents a major sustainable paradigm due to its volatile organic compound (VOC)-free nature, ultra-fast crosslinking, and high energy efficiency. However, imparting robust self-cleaning and antimicrobial functionalities into photopolymerizable matrices without compromising curing kinetics and adhesion durability remains a critical challenge.

This review evaluates recent advances in sustainable UV-curable nanocomposite coatings incorporated with heterogeneous zinc oxide–silver (ZnO–Ag) hybrid nanoparticles. We systematically analyze the physical, chemical, and biological synthesis pathways of hybrid fillers, emphasizing surfactant-assisted thermal decomposition routes (e.g., oleylamine-stabilized pathways) that successfully narrow the bandgap to 2.6 eV and ensure excellent colloidal stability within photopolymerizable resins.

The underlying mechanisms driving these dual-functional smart properties are deconstructed, highlighting the interfacial Schottky barrier at the $ZnO–Ag$ junction that suppresses charge recombination and extends photocatalysis into the visible daylight spectrum. Consolidated data underscores that a disciplined hybrid filler loading threshold (2 wt%) optimizes broad-spectrum antimicrobial disinfection (>99.9% against *E. coli*) via synergistic reactive oxygen species (ROS) generation and ion release, while maximizing interfacial mechanical properties, especially supreme substrate adhesion (Grade 0, ISO 2409). Finally, current challenges in silver-ion leaching, long-term weatherability, and industrial UV-LED scale-up are addressed.

Synthesis of Nb containing Beta zeolite catalysts and their application in the glucose retro-aldolization

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Non-edible cellulosic biomass is widely recognized as a renewable and readily accessible carbon resource for the future chemical industry, contributing significantly to the reduction carbon dioxides emissions. The fragmentation of biomass-derived sugars such as hexoses and pentoses can expand their potential utility through the formation of lower carbohydrates, which serve as versatile platform molecules (**Figure 1**). For example, glucose, the most abundant hexose derived from non-edible cellulosic biomass, undergoes retro-aldolization (RA) reaction to produce erythrose (C4 fragment) and glycolaldehyde (C2 fragment). The catalysts used in this reaction often simultaneously promote epimerization and isomerization, leading to the formation of mannose and fructose, respectively. Mannose can also undergo RA to yield C4 and C2 products, whereas fructose produces 1,3-dihydroxyacetone (C3) and glyceraldehyde (C3) via RA. Numerous studies have reported the formation of lactic acid and alkyl lactate via glucose isomerization, followed by RA.[1)] In contrast, there have been few reports on the direct production of these lower carbohydrates (C2, C3, and C4) from glucose. This is due to their high reactivity, arising from carbonyl moieties and multiple hydroxyl groups, promotes complex side reactions, making their selective formation and recovery challenging.

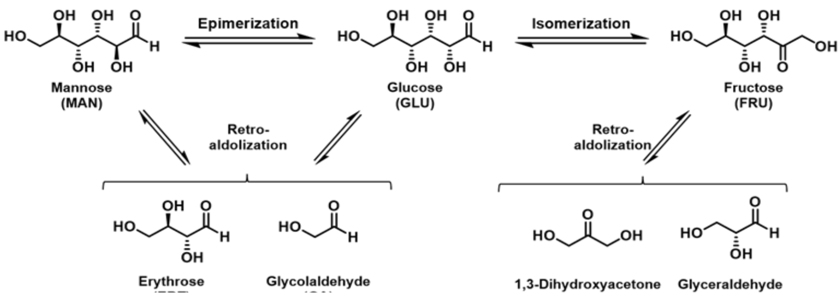

Figure 1. Reaction pathways of glucose fragmentation to lower carbohydrates via RA reaction

The objective of this study is to develop an effective solid Lewis acid catalyst for RA reaction of glucose. Our group has reported that unsaturated niobium species on Nb_2O_5 effectively work as Lewis acid sites for this reaction. Therefore, here we synthesized Nb-containing zeolites and examined their catalytic performance in RA reaction of glucose. The Nb-containing zeolites with BEA topology enabled the RA reaction to proceed even at relatively low temperatures (110 °C), where conventional Nb_2O_5 is inactive as much high temperatures are required (>150 °C) for Nb_2O_5 to function as a Lewis acid catalyst. Side reactions were significantly suppressed at such low temperature, affording C4 and C2 products with a combined selectivity of 40.5 %, respectively, along with a satisfactory carbon balance of 86.7 %, indicating efficient control of undesired reactions. Previous approaches have combined the RA reaction with selective acetalization to stabilize the products and enable their recovery as acetal derivatives. In contrast, the present system operates at a lower temperature, which suppresses undesired side reactions and allows direct formation and recovery of the desired products without the need for acetal protection.

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Low-Temperature Upcycling of Polyethylene via Integrated Reactor Design and Multimetal Catalysis

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Abstract

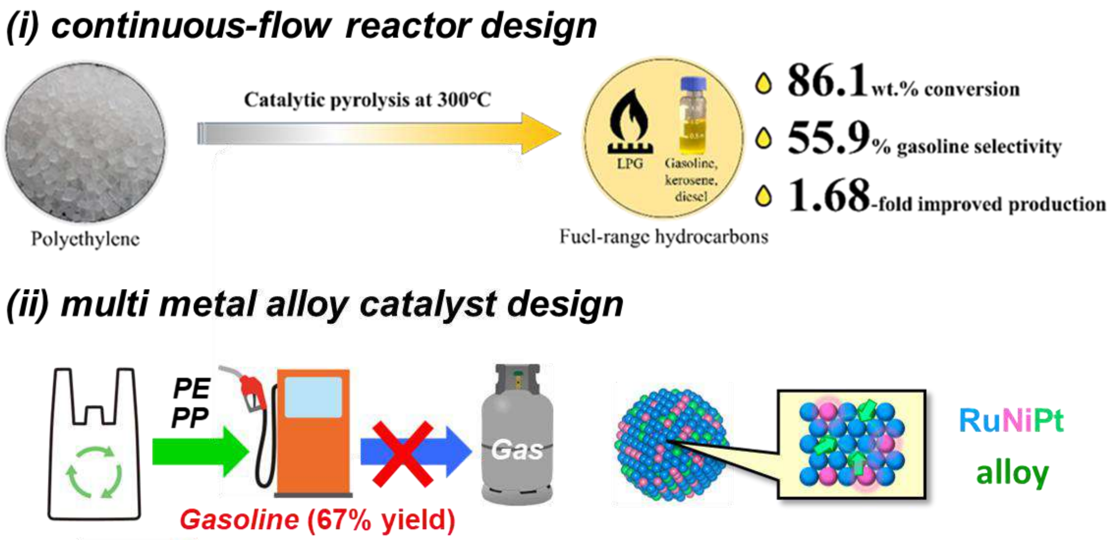
The catalytic upcycling of waste plastics into fuel-range hydrocarbons offers a promising pathway toward sustainable carbon utilization. However, the energy-intensive nature of conventional catalytic pyrolysis and the difficulty in achieving high selectivity toward gasoline-range products remain significant challenges.

In this work, heterogeneous catalytic depolymerization of polyethylene (PE) was systematically investigated using both batch and continuous-flow reactor configurations. To reduce reaction temperature and enhance conversion efficiency, a vertical tubular pyrolysis reactor with an optimized dual-stage feed–catalyst bed (feed-to-catalyst ratio of 5:1) was developed.[1] This design enables sequential cracking of intermediates, achieving 86.1 wt% conversion of PE at 300 °C, corresponding to a 1.68-fold improvement compared to a conventional single-stage system. The incorporation of large-pore zeolites, such as Faujasite and Mordenite, further improves product distribution, delivering a gasoline-range selectivity of up to 55.9%.

To address overcracking and methane formation, a ternary RuNiPt nanoalloy catalyst was designed for selective hydrogenolysis in a batch system.[2] Benefiting from synergistic interactions between Ru–Ni and Ru–Pt active sites, the catalyst achieves 94% conversion with 90% liquid selectivity and 67% yield of gasoline-range hydrocarbons (C5–C12).

These results highlight the effectiveness of integrating reactor engineering and multimetal catalyst design for enabling low-temperature, high-selectivity plastic upcycling.

Scheme I



References 1) *ACS Sustain. Chem. Eng.*, **2026**, *14*, 3282–3290. 2) *JACS Au*, **2026**, in press.

Catalytic cracking of Isoprene to aromatic compound and light olefins using zeolite Beta and ZSM-5

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Biomass is an important renewable fuel source due to its abundance, carbon neutrality, and potential to reduce environmental waste. Among bio-based feedstocks, natural rubber composed of cis-1,4-polyisoprene from *Hevea brasiliensis* is promising feedstock because of long-chain polymer structure. However, the widespread use of natural and synthetic rubber has led to significant waste accumulation, highlighting the need for efficient recycling and valorization of isoprene-based materials.

This study investigates the catalytic conversion of isoprene via cracking over ZSM-5 and Beta zeolites. Zeolites are well-known for their structural versatility, thermal stability, and tunable acidity, making them effective catalysts for hydrocarbon cracking. Catalytic cracking was performed at 500 °C under N_2 atmosphere, using polyisoprene as the feed polymer.

After isoprene cracking at 500 °C (Figure 1), ZSM-5 produced about 3 wt% coke, while Beta zeolite produced 11 wt% coke, suggesting that coke deposition is more pronounced in Beta zeolite due to its larger pore size. Zn incorporation improved the catalytic performance of both zeolites, increasing the yield of aromatic hydrocarbons through the dehydrogenation activity of Zn species. Also, Cr-modified zeolites showed reduced coke deposition during polyisoprene cracking. The Beta zeolite, characterized by its larger pore diameter, facilitated the formation of higher hydrocarbons, as its wider channels allow the diffusion and stabilization of intermediates (Figure 2). While the narrower pore structure of ZSM-5 promoted the production of lighter hydrocarbons due to enhanced shape selectivity. These findings highlight the potential of tailored zeolite catalysts for the sustainable conversion of polyisoprene into valuable chemicals.

Figure 1. Product distribution over polyisoprene cracking with ZSM-5 and Beta zeolites

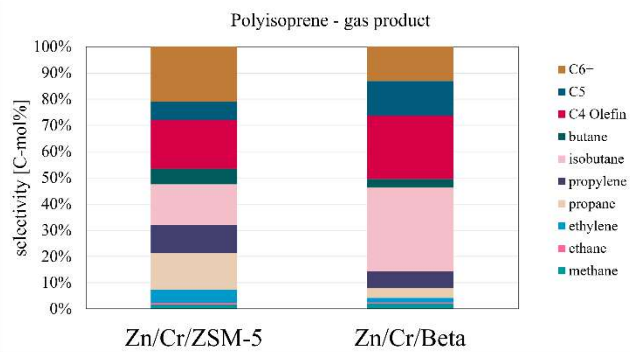

Figure 2. Comparison in gas product distribution for ZSM-5 and Beta zeolites at 500ºC, ½ ratio

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Second metal-modified Ru/CeO_2 catalyst for hydrogenolysis of LDPE

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Plastics are indispensable in modern society due to their durability, hygiene, and low cost; however, their rapid production and widespread use have resulted in severe environmental challenges, particularly from mismanaged waste such as ocean pollution.[1] Catalytic transformation of waste polyolefin plastics into value-added products offers a promising strategy for sustainable recycling. Among these approaches, hydrogenolysis using supported multi-metal catalysts enables efficient chemical recycling under relatively mild conditions. Ru-based catalysts are highly effective for cleaving C–C bonds in polyolefins.[2] This research work focused on bimetallic Ru-based catalysts to suppress the undesired gas production at low H_2 pressure.

Ru(x)-M(y)/CeO_2 catalysts (x, y: wt% loadings; CeO_2 calcined at 1173 K for 3 h) were prepared by sequential impregnation. Ru was first loaded onto CeO_2 and dried at 383 K for 12 h, followed by the addition of a second metal (M = Co, Ni, or Cu) and annealing at 573 K under N_2 for 1 h. Catalytic tests were conducted using 3.4 g LDPE ($Mn \approx 1700$ g mol^{-1}, $Mw \approx 4000$ g mol^{-1}) and 200 mg catalyst at 513 K under 0.5-1.0 MPa H_2 for 24 h. Gas and liquid products were analyzed by GC (CP-Sil 5 CB, DB-1).

The influence of incorporating a secondary metal into Ru(1)/CeO_2 catalysts was examined for the hydrogenolysis of LDPE under relatively low hydrogen pressures. Compared with Ru/CeO_2, the addition of secondary metals (Co, Cu, and Ni) significantly alters the product ratios, including gas, liquid, and wax fractions. Among the catalysts studied, Ru(1)-Ni(1)/CeO_2 catalyst exhibited higher conversion than Ru(1)/CeO_2 and the other metal-modified catalysts at a low H_2 pressure of 0.5 MPa with higher selectivity to valuable chemicals.

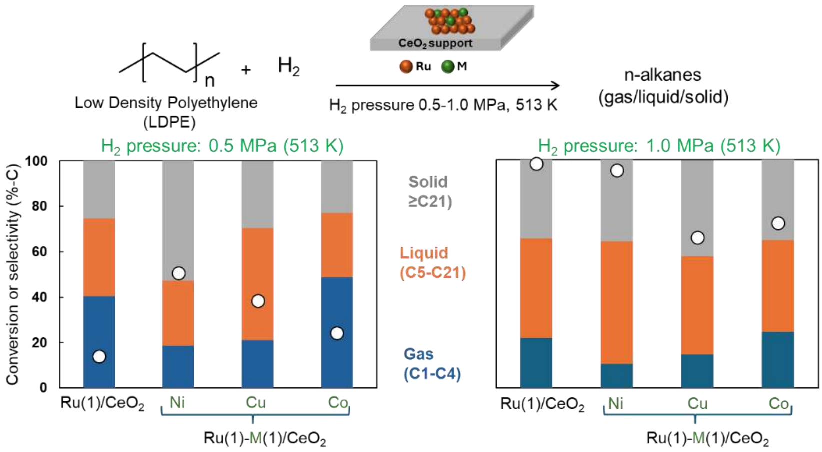

Fig.1: Conversion and product selectivity of the hydrogenolysis of LDPE over Ru(1)-M(1)/CeO_2 catalysts. Reduction conditions: 200 mg catalyst, 3.4 g LDPE, 0.5 or 1 MPa H_2, 513 K, 24 h.

References:

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Effect of Isocyanate Structure on Bio-based Poly(diethylene furanoate)-b-poly(caprolactone) Thermoplastic Polyurethanes

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Abstract

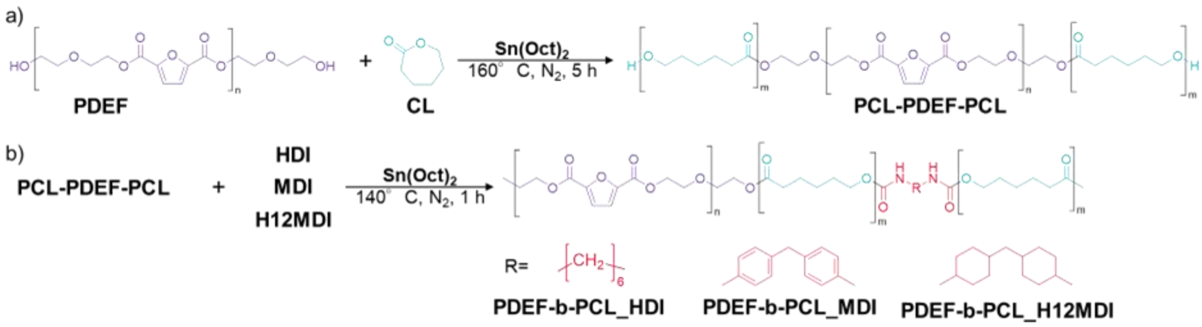
Thermoplastic polyurethane elastomers combine the durability and toughness of thermoplastics with the elasticity of rubber. However, since most conventional polyurethanes are fossil-based, the development of sustainable alternatives is essential. While the composition and phase separation of polyurethanes have been explored in detail, only a few reports have systematically examined the effect of isocyanate type on polyurethanes.

In this work, bio-based poly(diethylene furanoate)-b-poly(caprolactone) (PDEF-b-PCL) copolymers were synthesized via ring-opening polymerization of ε-caprolactone (CL) initiated by PDEF. Diisocyanates with three different structures were used as chain extenders: methylene diphenyl diisocyanate (MDI), hexamethylene diisocyanate (HDI), and dicyclohexylmethane 4,4'-diisocyanate (H12MDI) to systematically evaluate how their structure–property relationships of the resulting copolymers (**Scheme I**).

The copolymers consisted of a crystalline phase formed by PCL and an amorphous phase consisting of PCL and PDEF. For PDEF, due to its amorphous structure, the tensile properties were mainly influenced by the structure of the isocyanate, while for PCL-based samples, the governing factor was crystallinity. The copolymers exhibited remarkably enhanced elongation at break compared to the homopolymers, reaching up to 2400±300 %, which was attributed to strain hardening of the PCL crystalline domains and the amorphous PDEF segments acting as physical crosslinks that distributed stress. Some of the copolymers achieved superior toughness up to 2.3 MJ/m^3, compared to both PCL and PDEF homopolymers. The incorporation of PDEF significantly improved thermal stability.

Overall, this study demonstrates the potential of 2,5-furandicarboxylic acid-derived multiblock thermoplastic polyurethanes as high-performance, bio-based elastomers with tunable mechanical and thermal properties.

Scheme I *Synthesis scheme of PDEF-b-PCL copolymers with different isocyanates: a) ring-opening polymerization of CL with PDEF and b) chain extension reaction with three different isocyanates.*



Biobased phenol production via catalytic dealkylation of hydrocardanol over MFI zeolite catalysts

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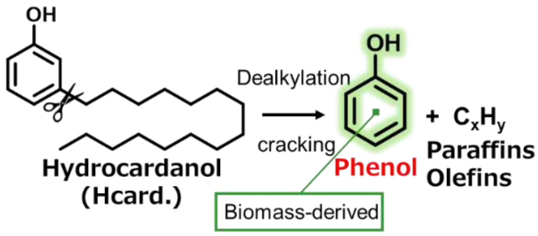

Figure 1. Dealkylation of Hydrocardanol

Phenol is currently produced from petroleum resources, but a transition to renewable carbon resources is required from a carbon-neutral perspective. In this study, we focused on hydrocardanol (Hcard), which is obtained by the hydrogenation of cardanol derived from cashew nut shell liquid (CNSL). Hcard is a phenolic compound bearing a C15 saturated alkyl chain at the meta-position of the aromatic ring (Figure 1). As CNSL is an agricultural waste-derived feedstock, Hcard represents a renewable, abundant, and underutilized carbon resource. Establishing an efficient dealkylation reaction system for Hcard using a solid acid catalyst would enable the production of biobased phenol from agricultural waste (Figure 1). As dealkylation and trans-alkylation reactions of biomass-derived alkylphenols has been extensively studied with zeolite catalysts, we investigated phenol production from Hcard over an MFI-type zeolite catalyst, a promising candidate for these reactions, in a fixed-bed flow reactor.[1)]

A time-dependent study conducted at 300 °C with a 1 wt% solution using MFI-type zeolite (SiO_2/Al_2O_3 = 80) revealed that a high PhOH yield of over 90% was maintained only during the first 4 h of the reaction. Simultaneously, alkyltoluene and lower olefins/paraffins with carbon numbers ranging from 2 to 4, were produced (Figure 2). These results indicate that MFI-80 catalyzed the dealkylation of Hcard and the cracking of the *in-situ* formed pentadecyl fragments, as well as the alkylation of toluene (the solvent) by the generated lower olefins. However, the catalyst activity gradually declined over time, indicating the deactivation of MFI-80 catalyst due to coke formation. In contrast, the same experiment conducted at 500 °C with a 10 wt% solution maintained a high PhOH yield for more than 6 h, and pentadecyl side chain in Hcard were predominantly recovered as lower olefins and paraffins, with a combined yield exceeding 80%. Both coke formation and sequential alkylation with lower olefins are largely suppressed under high-temperature conditions, enabling nearly quantitative phenol production. Therefore, the current process produces phenol and industrially valuable hydrocarbons can be simultaneously synthesized via dealkylation and cracking.

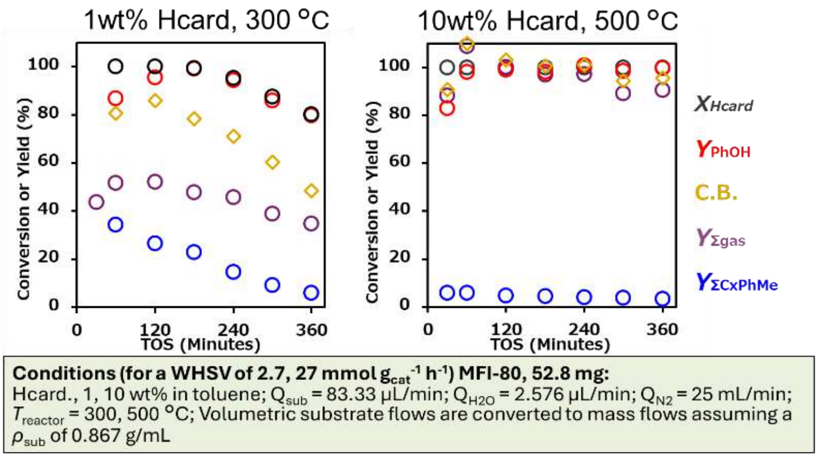

Figure 2. Time-dependence studies at 300 °C and

Reference

1) Jan J. Wiesfeld, Keisuke Iriba, Satoshi Suganuma, Emiel J. M. Hensen, Ryota Osuga, Kiyotaka Nakajima, *ChemSusChem*, **2025**, *18*, e202500401.

Trans-esterification of MFDC Using Solid Base Catalyst for Synthesis of Cyclic Monomers

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Poly (ethylene furanoate) (PEF) is a fully biobased polyester derived from non-edible biomass and has attracted significant attention as a viable replacement for petroleum-derived poly(ethylene terephthalate) (PET). Beverage-bottle applications require high molecular weight PEF, which cannot be synthesized via the simple polycondensation of dimethyl 2,5-furan-dicarboxylate (MFDC) and ethylene glycol (EG), but can instead be obtained via the ring-opening polymerization of cyclic monomers (**Figure 1**) [1,2]. In this study, we developed an efficient synthetic route to the cyclic monomers via trans-esterification of dimethyl furan-2,5-dicarboxylate (MFDC) with ethylene glycol using a solid base catalyst under environmentally friendly conditions.

Cyclic monomers were synthesized through a two-step trans-esterification reaction (**Figure 1**). In the first step, bis(2-hydroxyethyl) furan-2,5-dicarboxylate (BHEF) was formed via the trans-esterification of MFDC with EG. Systematic catalyst screening revealed that hydrotalcite, a layered double hydroxide possessing Lewis basicity, is a promising catalyst among various Lewis acid and base catalysts. After optimization of the reaction conditions, BHEF was obtained in 77% yield at full conversion in the presence of 20 equivalents of EG at 100 °C for 24 h. We are currently investigating the intermolecular cyclization of BHEF to synthesize the desired cyclic monomers. Hydrotalcite also exhibits high activity than other solid catalysts, but predominantly produces linear oligomers (*n*=2~4). To improve the yield of cyclic monomers, we are exploring reaction design based on templating effects of metal cations and spatial confinement effects using microporous and mesoporous materials.

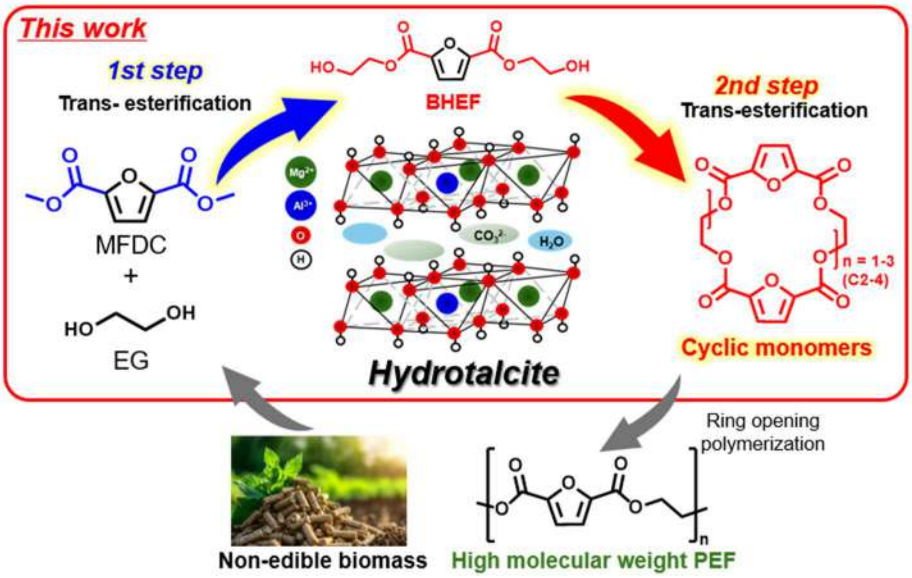

Figure 1, Synthesis of cyclic monomers via a two-step trans-esterification using hydrotalcite

References 1) J.G. Rosenboom *et al.*, *Nat. Commun.*, **2018**, *9*, 2701. 2) J.C. Morales-Huerta *et al.*, *Polymer*, **2016**, 87, 148.

Rapid Thermoresponsive Behavior of Poly(*N*-isopropylacrylamide) Hydrogels Enabled by Itaconic Acid-Modified Cellulose Fibers

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Abstract

Thermoresponsive poly(*N*-isopropylacrylamide) (PNIPAAm) hydrogels are widely utilized in biomedicine, sensors, and soft actuators due to their reversible volume phase transition. However, conventional PNIPAAm hydrogels exhibit inherently slow response kinetics, which remain a major limitation for their practical application in rapid actuation. To address this issue, various strategies such as interpenetrating networks and macroporous structures have been explored to accelerate response rates[1–3].

In this study, we propose the introduction of itaconic acid-modified cellulose (Cel-IA) nanofibers as cross-linkers to enhance both mechanical strength and response kinetics. A bio-based itaconic anhydride is used to modify cellulose, introducing multiple vinyl groups that serve as polymerizable cross-linking sites. The hydrogel was prepared via free-radical polymerization of *N*-isopropylacrylamide in the presence of Cel-IA, which acts as both a cross-linker and a reinforcing component (Cel-IA–PNIPAAm). The resulting hydrogel exhibited rapid deswelling behavior, outperforming both CNF-reinforced PNIPAAm and PNIPAAm hydrogels cross-linked with *N,N'*-methylenebisacrylamide (**Figure 1**). This enhancement is likely attributed to the formation of efficient water transport pathways facilitated by the hydrophilic Cel-IA network.

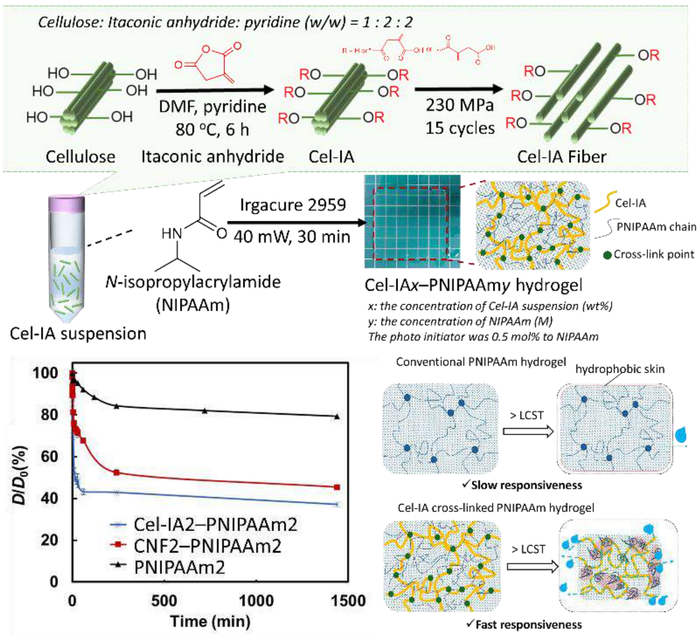

Figure 1. Preparation of Cel-IA–PNIPAAm hydrogels and thermoresponsive behavior of Cel-IA–, CNF, and conventional PNIPAAm gels.

References 1) M. Heskins, et al., *J. Macromol. Sci., Part A* **1968**, *2*, 1441. 2) X. Zhang, et al., *Soft Matter* **2008**, *4*, 385. 3) N. Harada, et al., *Carbohydr. Res.* **2023**, *528*, 108812.

Hydrogenolysis of Polyolefinic Plastics Over Low Ruthenium-Supported Catalysts

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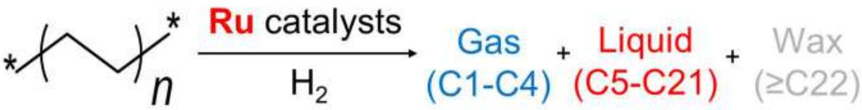
Abstract

Large amounts of plastics are produced worldwide, and a significant portion of them is not sufficiently recycled after use, leading to their accumulation in the environment. Polyolefinic plastics account for approximately 50% of total plastic production. Therefore, effective utilization of waste plastics, mainly composed of polyolefins, is an important issue. In this context, chemical recycling technologies that convert waste plastics into value-added chemicals have attracted increasing attention. Hydrogenolysis of C–C bonds in polyolefins is a promising approach for converting them into saturated hydrocarbons, which can be utilized as lubricating oils, fuels and so on.

In our laboratory, supported ruthenium catalysts (Ru/CeO_2 and Ru/ZrO_2) have been developed to exhibit high catalytic performance for polyolefin hydrogenolysis, producing liquid hydrocarbons (C5–C21) and waxes (C≥22)[1-4] (Scheme 1). However, due to the high price of ruthenium, there is a need for the development of catalyst systems consisting mainly of inexpensive metals for industrial applications, considering resource availability and cost. In addition, previous studies have mainly employed impregnation methods for catalyst preparation, and other preparation methods have not been sufficiently investigated.

To develop low-Ru-loading catalysts mainly composed of non-noble metals, we examined the effect of catalyst preparation method on the hydrogenolysis of LDPE. In this presentation, we will also discuss the reaction behavior of the catalysts.



Scheme 1 Hydrogenolysis of polyolefinic plastics over Ru-based catalysts

References 1) Y. Nakaji, et al., *Appl. Catal. B,* 285, 119805 (2021). 2) M. Tamura, et al., *Appl. Catal. B*, 318, 121870 (2022). 3) M. Tamura, et al., *J. Catal.*, 452, 116417 (2025). 4)Y. Kita, et al., *Catal. Today,* 461, 115492 (2025).

Effect of polyolefin structure on cracking behaviour over external acid sites of zeolite

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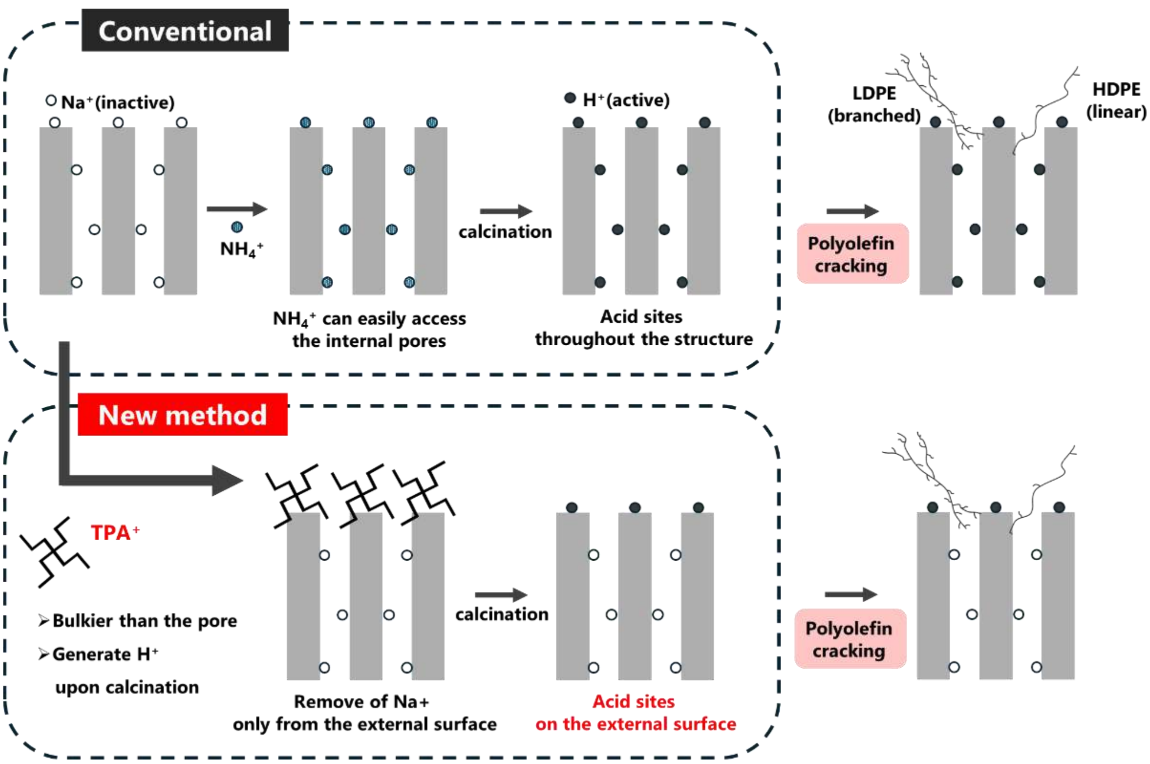
Chemical recycling of waste plastics has become increasingly important for achieving a sustainable society. Among various approaches, catalytic cracking of polyolefins over zeolite catalysts has been extensively studied, and distinguishing the roles of reactions occurring on the external surface and within the micropores is crucial for understanding the reaction mechanism. However, due to the significant size mismatch between polyolefin molecules and zeolite micropores, the accessibility of reactants to internal acid sites remains limited and complex.

In our previous study, we successfully synthesized a zeolite possessing Brønsted acid sites exclusively on the external surface and investigated its role in polyolefin cracking using low-density polyethylene (LDPE) as a model substrate. The results demonstrated the significant contribution of external acid sites in the initial degradation process, highlighting the importance of surface reactions.

When extending this approach to other polyolefins, the influence of polymer structure becomes a critical factor, as differences in chain architecture are expected to affect accessibility to acid sites and diffusion behaviour. Therefore, in this study, high-density polyethylene (HDPE), which has a linear structure distinct from LDPE, was employed for comparison (Scheme I).

As a results, the degradation temperature of HDPE was found to be higher than that of LDPE. This difference can be attributed to variations in polymer chain architecture: the linear structure of HDPE provides fewer accessible points to acid sites, whereas the branched structure of LDPE enhances accessibility. As a result, LDPE undergoes degradation at lower temperatures, leading to the observed difference in degradation behaviour.

Scheme I



Rational Non-Equiatomic Fine Tuning of High-Entropy Intermetallic Catalysts for Highly Durable Propane Dehydrogenation using CO_2

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Abstract

Propylene, a key building block in the chemical industry, can be efficiently produced via CO_2-assisted oxidative dehydrogenation of propane. However, catalyst deactivation due to sintering and coking remains a major challenge. To mitigate these issues, the use of CO_2 as a mild oxidant in propane dehydrogenation, i.e., CO_2-assisted oxidative dehydrogenation of propane (CO_2-ODP) has emerged as a promising alternative strategy. To achieve higher catalytic efficiency, we recently demonstrated that multinary alloys composed of these elements exhibit excellent performance in CO_2-ODP[1]. Furthermore, we found that extending these systems to high-entropy compositions significantly enhances the thermal stability of nanoparticles[2]. In this context, it is highly desirable to integrate and precisely control these strategies to develop more efficient catalysts for CO_2-ODP.

In this work, a series of high-entropy intermetallic catalysts with the composition $(Pt_{0.33}Co_xNi_{0.67-x})(Sn_yIn_{1-y})/CeO_2$ is developed, in which the configurational entropy and element-specific chemical contributions are systematically tuned. The catalyst with $x = 0.40$ and $y = 0.57$ shows higher net C_3H_6 selectivity and twice the catalyst lifetime compared with its equiatomic counterpart. A positive correlation between configurational entropy and nanoparticle dispersion is observed, quantitatively evidencing the entropy-contributed suppression of particle sintering. Kinetic analysis further distinguishes the respective roles of entropy-induced physical effects and element-specific chemical factors in determining catalyst stability. These results suggest that non-equiatomic compositional tuning is an effective strategy for improving high-entropy catalyst performance, opening a new avenue for the rational design of catalysts based on high-entropy materials.

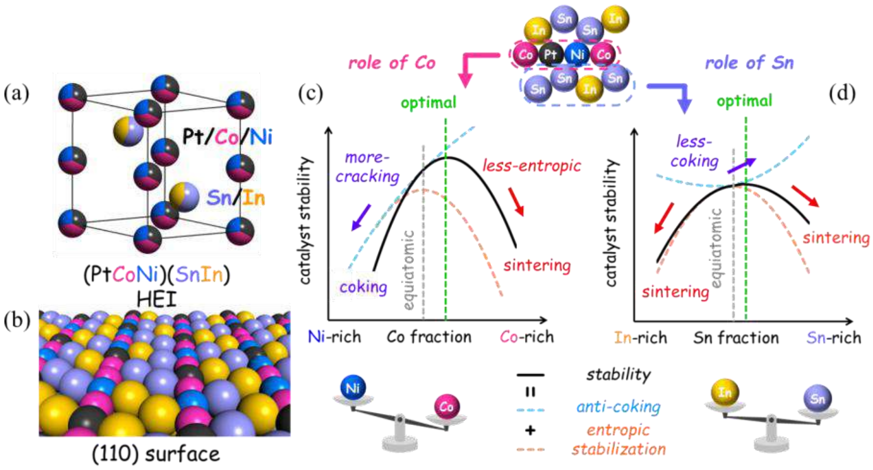

Figure.(a~d): Bulk and (110) surface structures of $(Pt_{0.33}Co_xNi_{0.67-x})(Sn_yIn_{1-y})/CeO_2$ HEI and schematic diagram on how Co and Sn tuning governs catalytic performance in CO_2-ODP.

References: (1) *Nat. Catal.*, **2022**, *5*, 55. (2) *Nat. Commun.*, **2022**, *13*, 5065.

Effects of Natural Weathering and Moisture Resistance of Titanium/Graphene-Coated Recycled Polypropylene/Oil Palm Empty Fruit Bunch Laminated Composite for the Roofing Material

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Abstract

The growing interest in wood plastic composite (WPC) for sustainable applications, particularly in the construction sector, highlights the need for surface enhancement strategies that improve their durability and performance under environmental exposure. This study focuses on the material resistance of WPC fabricated using recycled polypropylene (rPP) reinforced with oil palm empty fruit bunch (OPEFB). rPP/OPEFB samples were prepared using a two-roll mill and compression molding. As input parameters, the additive content, moulding temperature, and pressure-holding time have been considered. Although rPP/OPEFB composites offer advantages such as low weight and environmental sustainability, its hydrophilicity and surface imperfections limit long-term performance. TiO_2/G nanocoating was then applied via spraying method to enhance water repellence and degradation resistance. The study evaluates effects of TiO_2/G nanocoatings at different concentrations (0 - 5 wt%) on the water absorption resistance and UV-degradation of the rPP/OPEFB composites under natural weathering conditions. Flexural strength decreases by 76% and 56% for rPP/OPEFB(C)(without additive) and rPP/OPEFB(20)(with additive) compared to rPP/OPEFB(C) within 9 months of natural weathering exposure. Upon coating, 5rPP/OPEFB(C) and 5rPP/OPEFB(20) show enhanced strength by 11% and 31% compared to uncoated samples with/without coating. Samples with additives show an increase of thermal stability (T_{onset}) by 17 °C when coating with 5wt% TiO_2/G. Moreover, it also exhibits 5% reduction in water absorption compared to uncoated samples with additives after 28 days of immersion. The findings indicate that TiO_2/G nanocoating enhances thermal stability, moisture absorption, and environmental resistance when exposed to natural weathering, indicating considerable potential for outdoor applications.

Keywords: Recycled polypropylene, oil palm empty fruit bunch, polymer composites

Poster

Session ST

SATREPS

Science and Technology Research Partnership for Sustainable Development

Development of Graft Copolymers with Cellulose Acetate and CO_2-based Polycarbonate or Polyester

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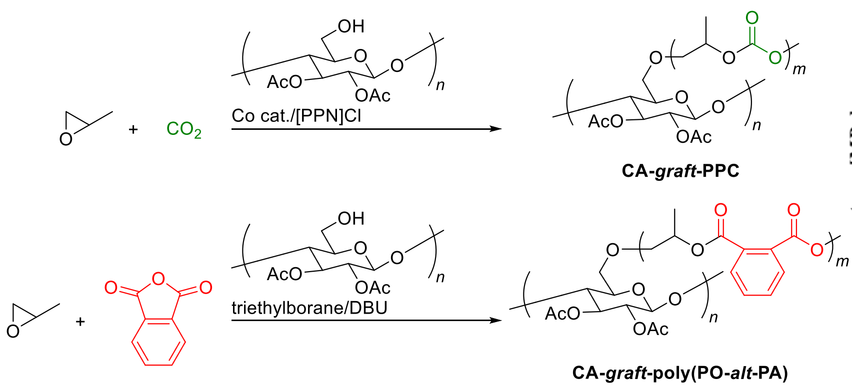
Abstract

The synthesis of aliphatic polycarbonates (APCs) by the alternating copolymerization of epoxides with carbon dioxide (CO_2) has attracted considerable attention as an effective approach for CO_2 utilization as a carbon feedstock. [1 and 2] However, the practical applications of APCs are limited because of their poor thermal stability and low mechanical strength. In this study, cellulose acetate (CA), a cellulose derivative with high thermal stability and mechanical strength, was introduced to improve the physical properties of APCs. Graft copolymers consisting of CA and poly(propylene carbonate) (PPC), a representative APC, were synthesized and characterized. [3] Similar investigations were also carried out for polyesters obtained by the alternating copolymerization of epoxides and cyclic anhydrides.

CA-*graft*-PPC, in which PPC side chains were introduced onto CA, was successfully synthesized by the alternating copolymerization of propylene oxide (PO) and CO_2 using the residual hydroxy groups of CA as chain transfer agents (CTAs) (Scheme 1). Similarly, CA-*graft*-poly(PO-*alt*-PA) bearing polyester side chains was synthesized by the alternating copolymerization of PO and phthalic anhydride (PA). Graft copolymers with different side-chain lengths and graft densities were also prepared by varying the monomer/CTA ratio and the degree of substitution of hydroxy groups in CA. The obtained graft copolymers were characterized by thermogravimetric analysis and differential scanning calorimetry, which revealed improved thermal stability and increased glass transition temperatures. Furthermore, CA-*graft*-PPC was found to enhance the mechanical strength of PPC-based blend films when applied as an additive (Figure 1).



Scheme 1.
Synthesis of CA-*graft*-PPC and CA-*graft*-poly(PO-*alt*-PA)

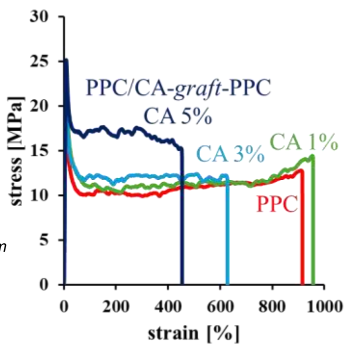


Figure 1. Tensile tests of PPC/CA-*graft*-PPC blend films

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Investigation of Physical and Chemical Properties of Cellulose from Rubber Seed Shell as an Alternative Cellulose Source

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Abstract

Rubber seed shell is an abundant agricultural residue from the rubber plantations, but it remains largely underutilized despite its high cellulose content. Valorizing this biomass as an alternative cellulose source could contribute to sustainable resource utilization. In this study, cellulose was extracted from rubber seed shells through alkaline pretreatment using 4% NaOH, followed by bleaching with 1.4% $NaClO_2$ at different bleaching cycles (1, 3, 5, and 7 cycles). The obtained samples were characterized by Whiteness index and brightness, Chemical composition, Fourier Transform Infrared (FTIR) Spectroscopy, Swelling behavior, Scanning Electron Microscope (SEM), and Thermogravimetric Analysis (TGA).

The results showed that the Whiteness Index and Brightness increased with the number of bleaching cycles, reaching the highest value of 89.9 and 73.9, respectively, after seven cycles. In addition, lignin content significantly decreased from approximately 33.5% to 2.7%, indicating effective removal of non-cellulosic components. FTIR analysis confirmed reductions in the functional groups of lignin and hemicellulose. SEM images showed that progressive bleaching removed surface impurities and revealed more distinct cellulose fibrillar structures, while swelling and TGA analyses revealed improved water absorption and good thermal stability of the extracted cellulose. These findings demonstrate the potential of rubber seed shells as a promising alternative cellulose source and highlight their value for the valorization of agricultural waste.

Research Keyword: Alkaline pretreatment, Bleaching, Cellulose, Lignocellulosic biomass, Rubber seed shell

Synthesis and Characterization of Polybutylene Succinate with Dimer Acid Derived from Plant Oil

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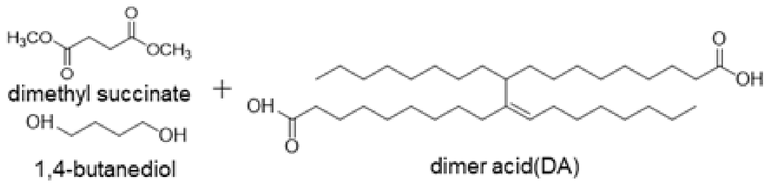
To address environmental concerns, it is important to utilize non-edible biomass resources. This study focuses on the seeds of Para rubber tree, a byproduct of the natural rubber industry. The rubber seeds (rubber seed oil, RSO) is a non-edible vegetable oil containing highly content of unsaturated fatty acids. Dimer acid (DA) is one of the materials synthesized from unsaturated fatty acids. The chemical structure of DA consists of dicarboxylic acid with long hydrocarbon chains. This structure gives flexibility and hydrophobic nature to polymers.

In the present work, we used DA obtained from other bio resources as a model compound of RSO to clarify the influence of the DA in the properties of polymers. Polybutylene succinate (PBS) containing DA was synthesized by transesterification reaction of dimethyl succinate and 1,4-butanediol as shown in Scheme **1**. The self-standing films were obtained by solvent casting method. The obtained polymers were analysed by FT-IR and ^{1}H NMR spectroscopy to confirm the chemical structure. Various properties of the polymers will be discussed in terms of the introduction of the DA content.



Scheme **1**

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