Optimizing the conditions of 3D Printing of Thermoplastics Composites with Carbon Nanotubes Using a Novel Pellet-fed material extrusion (PF-MEX) Process

Roxana Abdi

This work investigates the utilization of a novel Pellet-fed material extrusion (PF-MEX) 3D printing method for the production of various Thermoplastics such as Polylactic acid (PLA), Polyamides (PA), and polypropylene (PP) and their blends and composites. This innovative approach offers considerable benefits compared to traditional filament-based methods by enhancing process adaptability, offering more flexibility in terms of material preparation, and facilitating direct printing from pelletized components.

The research investigates the impact of critical processing conditions, such as extrusion temperature, build-bed temperature and extrusion rate, as well as the effect of material properties, such as viscosity, on strand consolidation and the mechanical properties of 3D Printed parts.

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Given that strand is of primary importance to ensure well-consolidated parts that have properties that approximate the bulk properties of the materials, a test method is developed to assess the fusion of the deposited strands, using a modified peel test, coupled with optical microscopy. The strength of the bonds is assesed as a function of the build-bed temperature, and correlated to the crystallization kinetics of the material, investigated by Differential Scanning Calorimetry. Furthermore, the effect of the viscosity on the processing characteristics and strand consolidation is also investigated. This investigation is expected to facilitate the selection of optimized processing conditions.

Optimized processing conditions are expected to lead to improvements in tensile and flexural strength and thus enhanced structural performance of printed parts. Furthermore, the influence of Nanofillers incorporation on the processability and the resulting part properties is also investigated, to assess the potential of these composites in functional applications.

The findings demonstrate the potential of this novel extrusion process for developing sustainable, lightweight, and functional materials with applications in transportation, electronics, and structural components.

The assessment of biochar addition on Anaerobic Co-Digestion

Faraz Arafati

Organic waste management plays a crucial role in sustainable development. Among various waste treatment methods, anaerobic digestion (AD) offers a key advantage: it produces renewable energy rather than consuming it. AD converts biodegradable materials into biogas and nutrient-rich digestate under oxygen-free conditions. However, when treating rapidly acidifying substrates such as food waste (FW) at high organic loadings, the process often faces instability, volatile fatty acid (VFA) accumulation, and inhibition.

Biochar has emerged as a promising strategy to overcome the major operational limitations of anaerobic digestion, including slow hydrolysis, VFA accumulation, ammonia inhibition, and process instability. Its porous structure and large surface area provide a favorable habitat for microbial attachment and enzyme activity, accelerating the degradation of complex substrates that typically limit AD performance. Biochar also enhances system robustness by buffering pH fluctuations, adsorbing inhibitory compounds such as ammonia and VFAs, and enabling direct interspecies electron transfer (DIET), which strengthens syntrophic interactions throughout the digestion stages. Through these combined effects, biochar improves process stability, supports methanogenic activity, and ultimately enhances biogas generation efficiency.

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In this study, two semi-continuous anaerobic digesters (Digesters A and B) were operated for over 180 days to evaluate process performance. As an alternative to frequent alkalinity addition, biochar—a carbon-rich, porous material produced by biomass pyrolysis—was incorporated into the system. Biochar's high surface area, buffering capacity, and ability to adsorb inhibitory compounds contribute to improved methane yield and process stability.

Future work in this project will employ a batch anaerobic co-digestion system using a substrate mixture of thermally treated sludge and food waste, designed to systematically evaluate the effects of iron-based biochar functionalization on digestion performance. Biochar will be modified using two iron salts—$FeCl_2 \cdot 4H_2O$ and Fe_3O_4—to generate three distinct functionalization pathways: Fe^{3+}-loaded biochar, Fe^{2+}-loaded biochar, and a dual-ion (Fe^{3+}/Fe^{2+}) composite, alongside an pristine biochar control. Each functionalization will be produced using a dedicated iron solution with tailored salt concentrations, and the resulting biochars will be introduced into the digesters at two different dosage levels to assess their influence on hydrolysis acceleration, inhibition mitigation, and methane generation. This experimental design aims to identify the most effective biochar modification strategy for stabilizing and optimizing anaerobic digestion of sludge–food waste mixtures.

Development of Self-assembled Ti3C2Tx MXene/rGO Hydrogels as Electrode Materials for Supercapacitors

Mohammad Bandpey

Supercapacitors are well-known high power density devices that store energy via electric double layer (EDL) formation. This mechanism demands electrode materials with high specific surface areas to maximize EDL space. Two-dimensional (2D) materials, such as reduced graphene oxide (rGO) and MXenes, are promising materials for EDL formation. One of the main advantages of 2D materials is their tunable interlayer spacing and ion-accessibility. However, due to van der Waals forces, their 2D nanosheets tend to restack during charge/discharge cycles, resulting in limited ion accessibility of the interlayer space. Here, we report the successful formation of Ti3C2Tx MXene/rGO heterostructures which are expected to have higher structural stability and resistance to restacking compared to their sole 2D counterparts. Additionally, MXene component introduces Faradaic redox contribution to the composite, resulting in improved energy density. In this study, Ti3C2Tx MXene/rGO composites with different MXene to rGO weight ratios are produced via a self-assembly process during hydrothermal reduction of MXene/graphene oxide mixture. The results are free-standing composite materials that are used as electrode substrates in aqueous supercapacitors. Respective supercapacitors are electrochemically characterized via galvanostatic charge discharge (GCD) and cyclic voltammetry (CV) techniques. Compared to pure rGO hydrogel, the produced MXene/rGO composite showed higher areal capacitance at a wide range of current densities. CV profiles proved that the higher capacitance in the composite hydrogel is due to Faradaic contributions of the MXene components in the composite material.

Development of Polylactide/Graphene Nanoplatelet Composites for Electronic Applications Requiring High Permittivity

Shivanthi Dharmarathna

Polylactide (PLA), a biodegradable bio-based polymer, offers a sustainable alternative to petroleum-based thermoplastics. Owing to its widespread applicability in 3D printing, it is a good candidate for 3D printed components for electronic devices. However, these applications require specific levels of electrical conductivity and/or permittivity, which are not typically possible by the unfilled polymer. This work aims to expand the functional applications of PLA in electronics applications, through the addition of graphene nanoplatelets (GNP). However, direct nanofiller addition by melt compounding can lead to agglomeration, reducing performance. In this work, to improve dispersibility, GNPs are non-covalently functionalized with trimellitic anhydride (TMA), aiming at improving the matrix-filler interactions. Evaluation of the interfacial energies and spreading coefficients indicated improved interfacial interactions with TMA modifications, while FTIR analysis did not show evidence of chemical bonding. At low filler contents, both composites exhibit well-dispersed GNP tactoids throughout the PLA matrix. As the filler content increases from 2.5 to 10 wt.%, larger aggregates and more interconnected structures form.

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TMA-GNP composites show improved dispersion compared to GNP composites, with fewer aggregated particles. GNP and TMA-GNPs increase the complex viscosity of the composites and eliminate the Newtonian plateau observed in neat PLA. The phase angle drops beyond 2.5 wt.% in PLA/GNP and 5.0 wt.% in PLA/TMA-GNP, observed in Van Gurp-Palmen plots, indicate the formation of a percolated filler network, enhancing elasticity. The electrical percolation threshold follows similar trends, being lower for PLA/GNP composites ($\phi c \approx 2.7$ wt.%) compared to PLA/TMA-GNP composites ($\phi c \approx 5.2$ wt.%), indicating that a network forms at higher concentrations in the latter. Both composites achieve similar maximum electrical conductivity of about 0.18 S/m at 30 wt.% and maximum thermal conductivity of 0.9 W/m.K. The relative permittivity shows significant enhancement at 30 wt.% GNP, while the loss tangent rises with filler content and decreases with frequency. Additionally, the GNPs have positive effects in the mechanical properties, including flexural modulus and impact strength. The flexural modulus shows a notable increase with the addition of GNPs and TMA-GNPs, with the enhancement being more pronounced in the GNP composites. The impact strength increases up to 20 wt.% filler content but declines at 30 wt.% due to filler aggregation.

Improving Cu-Mediated Reversible Deactivation Radical Polymerization Semi-Batch Systems for Acrylate Block Copolymers

Shizhe Dong

Cu-mediated reversible deactivation radical polymerization (RDRP) enables the synthesis of polymers with well-defined and well-controlled structures. Previous studies have employed activators regenerated by electron transfer atom transfer radical polymerization (ARGET ATRP) to establish a two-step process consisting of in-situ catalyst generation in a Cu-tube followed by semi-batch chain extension in a stirred vessel with continual feeds of monomer and a reducing agent. The semi-batch process offered good control and scalability for larger scale commercial production of acrylate-based homopolymers and block-copolymers, but preparation of the initiator/catalyst solution required longer times and limited precise control over Cu concentration.

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In this work, the process was simplified by directly adding CuBr2 as the copper source in a prepared initiator solution that was shown to provide comparable activation efficiency in the semi-batch process, thus eliminating the need for the tubular reactor. In addition, ascorbic acid was replaced with ascorbyl palmitate as the reducing agent, facilitating efficient synthesis of a broader range of non-polar acrylate polymers under mild operating conditions (60 °C). Kinetic investigations were conducted using a pseudo-batch system (i.e., batch except for the continuous addition of low levels of reducing agent), offering a more intuitive method to identify the influence of key variables, including temperature, copper level, solvent percentage, and reducing agent feed rate. The results showed that polymer dispersities below 1.5 can be maintained even with reduced copper levels. Finally, the optimized conditions were applied to produce isobornyl acrylate/butyl acrylate block copolymers, a material of interest for industrial application as a pigment dispersant. Well-defined and well-controlled polymerizations could be achieved, demonstrating the practical potential for scalable acrylate-acrylate block copolymer synthesis.

Intermittent Operation Strategy for Stable C2+ Production in an Aqueous CO2RR System

Guorui Gao

Electrochemical carbon dioxide reduction (CO2RR) offers a sustainable pathway to convert CO2 into valuable fuels and chemicals using renewable electricity, providing a promising route toward carbon neutrality. The long-term stability of copper (Cu)-based catalysts remains a major challenge for CO2RR, particularly under industrially relevant conditions. Here, we report a facile in situ catalyst fabrication approach coupled with an intermittent operation strategy that enables periodic sustainable performance and electrode recovery in a liquid-fed CO2RR system. The catalyst is directly deposited onto a silver substrate by electrochemical reduction of Cu2+ precursors in an acidic solution, forming a rough and porous Cu layer with abundant active sites. Subsequent CO2RR in CO2-saturated 0.1 M KHCO3 solution achieves a Faradaic efficiency beyond 60 % toward C2+ products, including over 30 % for ethylene at a current density of 200 mA/cm2. Remarkably, the deposited Cu layer can be readily removed by simple immersion in the original precursor solution, allowing complete electrode regeneration without complex treatments. The system demonstrates stable performance over >500 hours of intermittent operation (12 h on for CO2RR/12 h off for electrode recovery), highlighting a promising route for coupling CO2RR with renewable or off-peak electricity supply. This dynamic catalyst-operation strategy offers a practical pathway to extend overall system lifetime and reduce maintenance costs in scalable CO2 conversion systems.

Hydrothermal Liquefaction of Municipal Wastewater Sludge from the City of Kingston

Shabnam Ghanbarzadeh

As sludge generation continues to increase, conventional disposal methods are becoming economically and environmentally unsustainable. These challenges emphasize the need for efficient and eco-friendly alternatives. Hydrothermal liquefaction (HTL) has emerged as a promising waste-to-energy technology capable of converting high-moisture sludge into valuable products (biocrude, aqueous phase, char and gas) without the need for energy-intensive drying. In this study, response surface methodology was applied to evaluate the effects of key operating parameters on product yield and quality, including temperature (280–340 °C), residence time (10–60 min), and solid content (15–30 wt.%). Primary sludge from the Ravensview wastewater treatment plant was used, containing 16.57 g/L proteins, 27 g/L carbohydrates, and 2.35 g/L lipids, with total solids of 29 g/L and COD of 34 g/L.

After HTL, the biocrude, aqueous phase, and char were separated by filtration and solvent extraction for analysis. The biocrude yield ranged from 25–40%. GC-MS results showed that the biocrude mainly comprised oxygenated compounds (20–60%), including alcohols, ketones, aldehydes, acids, and amides, alongside hydrocarbons (10–30%). Hydrocarbons were formed primarily through decarboxylation of carboxylic acids, which act as key intermediates. Due to the low lignin content of sludge, phenolic compounds were minor (3–5%).

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Characterization of the aqueous phase revealed that it contains relatively high concentrations of chemical oxygen demand (COD) (50 g/L) and volatile fatty acids (VFAs) (9 g/L), indicating a significant presence of biodegradable organic compounds. These results suggest that AqP has strong potential as a substrate for biological treatment processes such as anaerobic or aerobic digestion. The elevated COD and VFA levels provide sufficient carbon sources for microbial growth and activity, making AqP a suitable candidate for energy recovery through biological conversion pathways while reducing its organic load before disposal or reuse.

Overall, the findings demonstrate the strong potential of HTL as a sustainable sludge management and energy recovery strategy. Optimization of process conditions can further enhance product quality and yield, reinforcing HTL’s role in advancing circular waste-to-energy systems.

Development of SERS-Based Microfluidic Platforms for Bioanalytical Applications

Namratha Gudigunti

Point-of-care diagnostic devices offer significant advantages over traditional laboratory testing, including reduced costs, faster results, improved accessibility, and the ability to perform on-site testing in remote areas or emergency situations where rapid decision-making is critical. Surface-Enhanced Raman Spectroscopy (SERS) is a highly sensitive molecular detection technique that provides label-free, non-destructive analysis making it well-suited for biosensing applications. Microfluidics enables precise control of sample volumes while SERS provides the sensitivity needed to detect analytes at low concentrations making this combination ideal for miniaturised diagnostic devices.

Initial efforts established SERS protocols using model compounds to understand fundamental detection mechanisms and optimize signal enhancement. These approaches were extended toward clinically relevant targets, specifically creatinine—a critical biomarker for kidney function assessment. Current work focuses on validating these detection methods for subsequent incorporation into microfluidic device prototypes for clinical applications.

Incorporating ARIMA-Inspired Disturbances in Fundamental Models for Online Use

Mouna Harb

Online fundamental dynamic models, which are used for process monitoring, provide important insights into process behaviour, especially when key states cannot be measured or when measurements are delayed and noisy. Some modelers add stochastic terms to their model equations to account for unknown disturbances and process-model mismatch. Extended Kalman filters and related state estimators consider these stochastic terms along with measurement noise while computing updated model states so accurate online predictions are obtained. In this study, we extend the types of stochastic disturbances used in state estimation by considering autoregressive integrated moving average (ARIMA) disturbances that are used in linear empirical time-series models for chemical processes. We propose a new approach for incorporating ARIMA-inspired empirical disturbance terms in nonlinear differential equation models and we show how empirical model parameters can be estimated along with fundamental model parameters using historical operating data. A case study involving a continuous stirred tank reactor (CSTR) is used to demonstrate the potential of the proposed parsimonious hybrid-modelling approach.

Lab-scale production of graphene oxide nanoplatelets by electrochemical exfoliation for use in the separation of isotopic water mixtures

AmirAria Latifzadeh

This study investigates the lab scale production of graphene oxide (GO)-based membranes for isotopic water separation. Efficient separation and reuse of water hydrogen isotopes are crucial in nuclear energy production and contribute to the development of more environmentally friendly processes. Traditional separation methods, such as distillation, are energy-intensive, thus not very economically attractive. On the other hand, membrane-based separation, particularly using GO membranes, offers a more promising solution due to lower energy requirements and improved cost-effectiveness. However, separation efficiency and mixture processing capacity are key challenges in membrane-based techniques. To address this, we aimed to improve these aspects by optimizing the lab scale production of GO platelets, the fundamental building blocks of GO membranes.

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This work focuses on the fine-tuning of the physicochemical properties of GO platelets, the building blocks of GO membranes, in order to maximize the separation efficiency of the latter. The GO platelets used for membrane fabrication were produced by an electrochemical intercalation and oxidation process, followed by ultrasonication. The GO membranes were produced through pressure-driven filtration on the resulting GO dispersions. The study aimed to understand how key process parameters, such as electrical potential and current, exfoliation time, and sonication influence the properties of the resulting GO membranes, including oxidation degree, size distribution, surface and structural defects. These characteristics are critical in determining the membranes' ability to selectively separate water isotopes.

The relationships between the electrochemical reaction conditions and GO membrane properties were analyzed using various spectroscopic and imaging techniques, light scattering, and filtration experiments. The findings provided valuable insights into how oxidation levels and platelet defects affect membrane performance. This work also produces product design guidelines for developing more efficient and customizable GO membranes.

Modulation of local environment for selective bicarbonate conversion to multi-carbon products

Tai Nguyen

Direct electrosynthesis of C2+ products such as ethylene from bicarbonate offers a sustainable route for CO2 utilization but is hindered by limited CO2 availability and unfavorable reaction environments. Existing approaches such as electrolyte engineering and buffering layers, often improve selectivity at the cost of higher cell voltages, creating a trade-off between selectivity and energy efficiency. Here, we introduce a new electrode design for direct bicarbonate conversion using highly porous copper electrodes coated with a carbon/ionomer layer. Multiphysics modeling results reveal that electrodes with large pores enable high CO2 availability but suffer from low local pH, unfavorable for C2+ product formation. We found that partially coating a large pore Cu electrode with a carbon/ionomer layer enables fine tuning of the local reaction environment to favor C2+ products while maintaining high CO2 availability for high reaction rates. This integrated design achieves ethylene Faradaic efficiencies of 43 % (total C2+ FE of 60 %) at 150 mA/cm2 with cell voltages as low as 3.38 V. When coupled to a dilute CO2 source (20% in Ar), the system sustains > 30% ethylene FE for ~ 150 h at 150 mA/cm2.

Measurement of Radical Polymerization Kinetics of Sparingly Water-Soluble Monomers in Organic and Aqueous Solvents

Fatemeh Salarhosseini

Waterborne polymer dispersions, widely used for a variety of applications, are primarily synthesized through emulsion radical polymerization. Despite extensive research into this heterogeneous process, most models do not consider the substantial difference in the (co)polymerization kinetics of monomers in the continuous aqueous phase and the non-polar polymer particles. Recent studies indicate that solvent polarity influences both the propagation rate coefficient (kp) values and the copolymerization reactivity ratios due to the relative strengths of monomer-monomer and monomer-solvent hydrogen-bonding in the two phases. Therefore, it is vital to develop experimental procedures to measure kp and reactivity ratios in aqueous solutions under conditions as similar as possible to the real emulsion polymerization system. Given the hydrophobic nature of the commonly used monomers in emulsion polymerization —such as methyl methacrylate (MMA), butyl acrylate (BA), and styrene—the approach taken in this study is to investigate the copolymerization of similar non-functional model monomers possessing enhanced water solubility. Di(ethylene glycol) methyl ether methacrylate (DEGMEMA) and methyl methacrylate (MAA) can be considered as a non-functional and functional model monomers for MMA, respectively, and methyl acrylate (MA) and acrylic acid (AA) for BA.

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This study employs Pulsed-Laser Polymerization coupled with Size Exclusion Chromatography (PLP-SEC) analysis and in-situ NMR technique to investigate the systematic shifts in MA/DEGMEMA reactivity ratios and kp values with monomer concentration and water/ethanol composition ranging from pure ethanol to pure water. The study demonstrates that the reactivity ratios required to model copolymerization within polymer particles can differ significantly from those that accurately represent aqueous-phase reactions in emulsion copolymerization. However, acrylate–methacrylate compositions in aqueous solution are effectively described using a single set of reactivity ratios, independent of monomer functionality. Furthermore, the composition-averaged propagation rate coefficient, $k_\mathrm{p}^\mathrm{cop}$, data shows that, although noticeable differences exist between these values in the bulk phase, the k_p values tend to converge toward similar magnitudes in aqueous systems. This convergence aligns with the observed copolymer composition results, reinforcing the idea that aqueous environments promote more uniform copolymerization kinetics across different acrylate–methacrylate systems due to the strong influence of water-induced hydrogen bonding on all species.

Self-Assembled vanadyl sulfate-graphene hydrogel-based cathodes for high capacity aqueous zinc-ion batteries.

Andrew Sellathurai

This seminar is concerned with a novel strategy for synthesizing vanadium-oxide-based cathode materials for zinc-ion batteries. In the first step of the synthesis process, a vanadium graphene hydrogel is prepared via a hydrothermal reduction of a graphene oxide dispersion containing vanadyl sulfate. In the second step, the vanadyl content in the vanadium graphene hydrogel is further increased and then converted to vanadium pentoxide in another hydrothermal step. The obtained vanadium pentoxide-graphene hydrogel substrates are investigated in terms of material and electrochemical characteristics. At a current density of 0.1 A g−1, normalized with the entire cathode mass, an excellent discharge capacity of 502 mAh g−1 is achieved. If performance is normalized with the electroactive material vanadium pentoxide, this value increases to 669 mAh g−1. This outstanding value is not only a result of the reversible intercalation of zinc ions into the vanadium pentoxide but is also achieved by the simultaneous intercalation of protons and the capacitance of the high surface area graphene host material.