DEPARTMENT OF CHEMICAL ENGINEERING

UMass Amherst
The Commonwealth's Flagship Campus

Ph.D. Dissertation Defense

Thursday, August 11th, 2022
10:00 A.M. – Zoom Virtual Meeting (https://umass-amherst.zoom.us/j/8382285527)

"POLYESTERS DERIVED FROM BIOBASED 1,5-PENTANEDIOL FOR COATINGS, ADHESIVES, AND BIODEGRADABLE PLASTICS"

Lei Zheng

ABSTRACT

Biomass-derived polymers are drawing increased attention from researchers due to unique performance attributes, potential for biodegradability, new low-cost feedstocks, and improved sustainability. Biobased feedstocks are employed in both major applications of polymers thermostats and thermoplastics. For thermost coatings and adhesives, biobased resins such as biobased alkyds, epoxy resins, benzoxazine resins, starch derivatives, and proteins from plants and animals, are promising candidates to replace petroleum-derived counterparts. Thermoplastics such as polyethylene are mainly produced from fossil resources, generally have poor degradability and are difficult to effectively recycle. Currently, in the United States, less than 10% plastics are recycled, and more than 70% are landfilled. The plastics escaping from the waste management system will ultimately find their ways to oceans. Therefore, there is an urgent demand to develop degradable, recyclable, and biobased alternatives to replace conventional plastics. Although biobased materials continue to grow, petroleum-derived polymers still account for the majority of markets. To compete with the conventional thermostats and thermoplastics, biobased alternatives are required to overcome technical challenges, to provide equivalent or better performance, to become more environmentally friendly, and to offer equivalent or lower price.

In this thesis, we applied 1,5-pentanediol (PDO), which is an emerging biobased and low-cost monomer, to thermost coatings, adhesives, and biodegradable plastics. Polyesters based on PDO were designed, synthesized, and investigated. We developed a reactor for melt polymerization and understood the effects of reaction conditions to synthesize target polyesters with molecular weights ranging from 1KDa to over 100KDa.

First, various low molecular weight polyester polyols were characterized for end group compositions, monomer incorporation and thermal transitions. Bio-PDO-based coatings exhibited performance, including hardness, flexibility, adhesion strength, and solvent resistance, similar to the coatings based on petroleum-derived 1,6-hexanediol (HDO). Bio-PDO-based adhesives exhibited lower green strength (initial adhesion strength) and longer open time (workable time to bond substrates) than HDO-based adhesives. The effects of common biobased impurities, such as lactones (delta-valerolactone as an example of impurities), on polyester polyols were studied. We found hydroxyl functionalities of polyols were mainly controlled by the excess diols in monomer feeds instead of ring-opening polymerization of delta-valerolactone.

Second, high molecular weight aliphatic-aromatic polyesters, poly (pentylene adipate-co-terephthalate) (PPAT), were successfully synthesized via thin-film polymerization and chain extension. The effects of reaction temperature and catalyst on molecular weight were investigated. The final PPAT co-polyesters were characterized for microstructure, mechanical properties, and biodegradability. We have achieved PPAT compression films with 1.5 times tensile modulus than petroleum-based poly (butylene adipate-co-terephthalate) (PBAT), and comparable mechanical properties with low density polyethylene. Meanwhile, our preliminary results show PPAT films exhibited biodegradability similar with PBAT in soil.

The public is cordially invited to attend.