Biorenewable Polymers for Energy and the Environment

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A great challenge to overcome is the replacement of traditional petroleum-based plastics with polymers derived from sustainable, alternative resources. Though there are many facets to the design of truly sustainable materials, including the raw material source, energy demands of processing, and fate of the material post-consumer use, utilization of a more eco-friendly raw material source is an important first step. Ultimately, the full life cycle of the materials must be evaluated, including end-of-life options such as recycling, composting, and disposal in landfills. Of particular interest to our research group is the design of structured polymers from sustainable, plant-derived sources with well-defined molecular characteristics and competitive properties to conventional, petroleum-derived materials. We are developing a diverse array of polymers derived from plant sources spanning many classes of materials, such as thermoplastics, thermoplastic elastomers, and elastomers. The raw material sources that we have employed are vegetable oils (such as soybean and castor oils), plant sugars, biobased phenolic acids (found in fruits and vegetables), and rosin acids (found in conifers).

Vegetable oils are an attractive source for polymers, due to their low cost, abundance, annual renewability, and ease of functionalization. Long-chain polyacrylates derived from vegetable oil-based fatty acids have been investigated as components of thermoplastic elastomers, polymers which behave as an elastomer at room temperature yet are processable at elevated temperatures. The thermal and mechanical behavior of the polymers can be readily tuned through variation of the alkyl chain length of the fatty acid.

Phenolic acids are sustainable, plant-derived chemicals found in a variety of natural sources such as the skins, seeds, and leaves of fruits and vegetables. Phenolic acids are advantageous sources for polymers due to their aromatic rings, which provide mechanical strength, and the presence of carboxyl and hydroxyl groups, which provide routes to polymerization. Two classes of materials were investigated derived from phenolic acids: soft thiol-ene elastomeric networks (appropriate for applications such as coatings and adhesives) and epoxy resins (found in a variety of composite materials, such as wind turbine blades). Fundamental relationships between the molecular structure of the phenolic acids and the thermal and mechanical properties of the resulting polymers have been developed.