

BIO-BASED MATERIALS DESIGN AND PROCESSING GROUP

An ICTAS Focus Area

The Need for Bio-Based Materials

The rapidly expanding global industrial economy is based on fossil fuels. These fuels are finite resources that are rapidly being depleted; petroleum, the most convenient source of transportation fuel, is not only in short supply, but in many cases is located in states that may be unstable, hostile, or may be inclined to ration supply. The rapid growth of second and third world economies, with concomitant rise in standards of living, is exacerbating the pace of depletion. The world needs new feedstocks for fuel and materials to support these growing economies. Biomass is a leading candidate feedstock. The conversion of biomass to biofuels has huge potential to create a sustainable basis for global industrial economies with much reduced environmental impact. This will create the potential for biorefineries that produce both biofuels and advanced biomaterials, in close analogy to petrochemical refineries. The complex structures of polysaccharides and proteins provide enormous potential for tailoring to achieve outstanding performance, but they also necessitate the development of sophisticated methods for purification and modification of these materials, and detailed knowledge of structure-property performance relationships. The payoff will be the replacement of petrochemical-based materials with sustainable biomaterials, which often will be more benign from the perspectives both of environmental impact and of toxicity. The Virginia Tech Bio-Based Materials Design and Processing Group is developing technology to produce bio-based industrial products in sustainable ways, thus addressing society's need for high-performance products, and enhancing quality of life through sustainable and environmentally-friendly production.



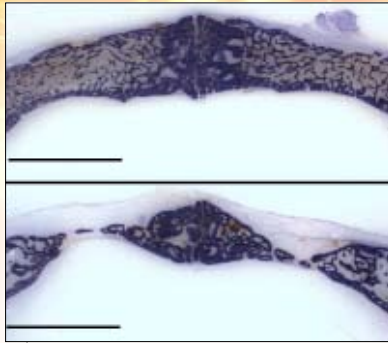
Team members undertaking Life Cycle Assessments (LCA) of the environmental impacts for products, processes, and systems.

Vision

- We will create knowledge to enable efficient biorefining of bio-based materials, design of enhanced bio-based materials, and utilization of these materials in high performance applications that will facilitate creation of a sustainable, secure, environmentally benign, biorefinery-based economy.
- We will create exceptional new educational opportunities for students in bio-based materials that cross traditional disciplinary boundaries of biology, chemistry, and engineering.
- We will communicate to the public the wealth of opportunity for biorefineries and bio-based materials to deliver performance while reducing environmental impacts and achieving sustainability as part of a bio-based economy.
- We will create opportunities for involvement in the Center by companies throughout the biomaterials industry. The industry will be involved in advising the Center, continuing education, creating the research agenda and program, networking, and eventually in taking advantage of commercial opportunities created by the Center.

Our Approach

Manipulation of molecular and nano-scale structures of biopolymers for the design and development of a bio-based material platform adaptable for a wide range of applications, including drug delivery, energy, packaging, structural materials, and tissue engineering. Design of selective separation processes that permit isolation of individual biopolymers or biopolymer fractions from natural sources to facilitate processing into fuels or biomaterials. Consideration of the full life cycle of products and processes to understand all of the environmental impacts and to avoid shifting environmental burdens from one area to another.



Cell-biopolymer interactions to optimize biodegradable scaffolds for improved tissue regeneration.



Bio-based polymers from proteins, polysaccharides, and fats.



Examples of biodegradable plastics made from feathers and eggs.

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Learning from Nature

Although nature builds optimal structures in a very rational manner, it does not do so quickly. Most biopolymeric structures take weeks to years to assemble and their optimal design has evolved over millennia. Nature does build structures using the "greenest" chemistry, i.e., biopolymers are synthesized from aqueous solution using enzymatic catalysts at 25-37°C and then assembled based on the interactions of the biopolymers with their environment in the absence of heat or large deformations. In contrast, synthetic polymers have evolved from petroleum in a relatively short time, about 60 years, and require solvents, heat, and pressure to produce. Synthetic polymers can be processed into their desired shape in seconds to minutes.

To date, there has been only mild academic interest in how biopolymers are synthesized and formed into structures. This was because whatever biopolymers were used were for food or wood. Now, petroleum prices have risen dramatically and there is interest in how biopolymers are synthesized and assembled because they could in principle serve as replacements for synthetic polymers. It would be advantageous to build high performance biopolymer structures the way nature does but on the time scales that made synthetic polymers cheap when petroleum supplies were plentiful.

Research Areas

- Biofuel feedstock from microalgae, biogas production from animal waste, and developing high-value nutraceuticals from biodiesel waste stream
- Chemical and fuel production through pyrolysis of biomass
- Efficient sugar liberation from biomass and biofuels production
- Polysaccharide derivatives for enhanced drug delivery
- Polysaccharide nanocrystals for biomedical applications and materials
- Layer-by-layer assembly of polysaccharides
- Biopolymer surface characteristics
- Bioprocessing and biomaterials
- Life Cycle Assessment of Bio-based Materials and Processes

2007 Accomplishments

- Group now includes 11 PIs and over 30 graduate students
- Submitted two proposals that include all PIs
- Formed Bio-based Materials Center (BBMC)