Composites Made from Polymers Reinforced with Cellulose Nanocrystals

Cellulose nanocrystals (CNCs) are being investigated as a reinforcement material in polymer composites with enhanced mechanical and physical properties; however, a number of technical challenges remain.

Remarkably, CNCs are about as strong as Kevlar® fibers, so they have tremendous potential for reinforcing plastics. We have already observed modest improvements in the strength of polypropylene with the addition of only 2% CNCs, and additional improvements are expected. In this research, we seek to optimize the system chemistry, composite morphology, and preparation methods to further enhance the mechanical and physical properties of thermoplastics reinforced with CNCs.

Micrograph of cellulose nanocrystals.

Recently, nanoparticles have been intensively investigated for use in polymer composites because of the unique performance advantages they offer at much lower loading levels than their macroscopic counterparts. Nano-scale reinforcing fibers can also be derived from wood. The tiny crystalline regions, of which CNCs are composed, are the strongest component of wood fibers and are about ten times stronger than the wood fibers themselves. These CNCs typically have high aspect ratios, with diameters of about 10 nm or less and lengths of hundreds of nanometers. Because of their small size, high aspect ratios, and remarkable strength, CNCs are a logical choice for reinforcing thermoplastics.

Background

Fillers and reinforcements are used to influence the mechanical performance of polymers and include materials such as glass and carbon fibers, calcium carbonate, talc, and mica. Filler and reinforcement materials from wood and other plant-based materials are also becoming widely used. For example, wood flour is added to thermoplastics as a low cost filler to alter mechanical performance, especially the stiffness of low melt temperature, commodity thermoplastics such as polypropylene and polyethylene, without increasing density as much as do many other filler and reinforcement materials.

Objectives

The specific objectives for this project include the following:

• Isolating and modifying CNCs so that they are thermally stable and compatible with polyolefins and other non-polar polymers.

• Producing CNC-reinforced plastic composites that have good dispersion.

• Relating composite morphology and polymer-CNC adhesion to performance.

- Optimizing the composite performance and preparation methods, giving consideration to practical economic and processing limitations.

- Exploring novel properties and applications of composites made with CNCs.

Approach

Plastic composites are being made with polyolefins and CNCs using various methods and treatments to enhance compatibility and improve dispersion. These composites are then extruded (or molded) into fibers (or other geometries) that are tested for mechanical performance and physical properties. Various microscopy and thermal analysis methods are used to investigate morphology and suggest avenues for further refinement. Treatments and composite preparation methods are then modified to enhance the dispersion, adhesion, and alignment of CNCs in thermoplastics.

Expected Outcome

Early analyses have shown that considerable reinforcing potential remains and that greatly improved composite performance is likely. By optimizing the reinforcement potential through better isolation and chemical modification techniques and improved composite preparation, we believe that CNCs will soon be competitive with other nanoparticle fillers in both performance and cost.

Timeline

Isolation and modification of CNCs are a major focus of the current work and will continue. Preparation of composites with CNCs began in 2007, and the optimization composite morphology and preparation methods are expected to continue through 2009.

Contact Information

Ron Sabo
USDA Forest Service
Forest Products Laboratory
Madison, Wisconsin
(608) 231-9530, rsabo@fs.fed.us