

BIOPHOTONICS

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Clean, New Bioenergy Sources: One Molecule at a Time

By Jessica Cox-Poo, Ph.D.

Penn State University's Hancock Lab is spearheading a multidisciplinary research effort to investigate the mechanisms of Cellulase enzymes on cellulose degradation, with the aim of developing more efficient biocatalytic production. To facilitate the research, the team has developed a multimodal microscope it calls "Scatterlight," based on the TMSD microscope.

The Hancock Lab, the Anderson Lab, and the Tien lab make up the Penn State (PSU) team, and their expertise encompasses biomedical engineering, biophysics, cell biology, and biotechnology. They are joining forces to explore ways to produce bioethanol more efficiently from lignocellulose (also called lignocellulosic biomass). Importantly, this is not corn ethanol (it is ethanol derived from corn stalks, switch grass, some kinds of poplar trees, and other fast-growing weeds). Since this material typically is composted, its use addresses the ethical, economic, and political questions about using food for fuel.

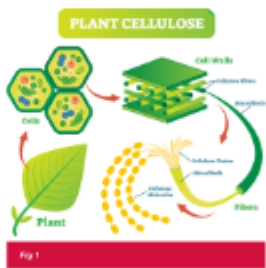
The Problem
Lignocellulosic plant material contains viable material for chemicals, construction materials, packaging materials, and other products (including bioethanol), but production of these high-value products is currently too inefficient to be economically viable. Post-2015, there was impetus for energy independence which, combined with a new emphasis on sustainable technologies, led to extensive research into applying enzymes and fungi commonly found in nature to convert plant waste into bioethanol. Geopolitical forces, combined with climate change concerns, provide additional motivation to solve this problem.

The Science
If one is to efficiently create biofuel, it is vital to understand the fundamental mechanisms of cellulose conversion in plants. Plant cell walls are made up of three basic compounds: cellulose, lignin, and hemicellulose/pectin. Different plants — based on their size, structure, age, and/or use — have different compositions and organization of these three components.

Cellulose, the most abundant cell wall component, is a long polymer of glucose molecules. While glucose is very soluble, it cell walls tie these together into strands that stack into organized, highly resistant cellulose microfibrils (Fig. 1).

Plants have evolved to make structures that resist enzymes, weather, bugs, fungi, and other parasites. Thus, it is difficult to degrade cellulose into glucose subunits that can be used as an energy source. The basic approach taken at the industrial scale begins with breaking down the lignin, accomplished through harsh steam treatment (pulsed steam) or using a color leaching agent or base (or the situation required) to break down the lignin. The hemicellulose and pectin are softer, more susceptible to acid, carboxylic acid, and base treatment also helps break out.

Following this pretreatment, cellulose is typically broken down using a cocktail of enzymes sourced by fungi. Two general types of enzymes act on these chains: exoglucosidases, which degrade the chain from the ends, and endoglucosidases, which cut the chains in the middle to create new ends for the exoglucosidase to degrade. The product of this cellulose degradation is a free-glucose sugar called



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Researchers at Penn State University are spearheading a multidisciplinary research effort to explore ways to produce bioethanol more efficiently from lignocellulose. Importantly, this is not corn ethanol; it is ethanol derived from corn stalks, switch grass, and fast growing weeds which would be otherwise composted. In order to investigate the enzymatic breakdown of cellulose and explore the optimum efficiencies that can be obtained, the Hancock lab at Penn State employed various microscopy techniques with the aid of a unique single molecule microscope.

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