Bio-Inspired Systems for Solar Energy Conversion

Neutron investigation of biomolecules is helping scientists develop synthetic, bio-inspired systems for solar energy conversion.

Natural photosynthetic systems have developed a complex machinery for efficient conversion of sunlight to chemical energy, which to the present day has not been matched by human-made technologies. ORNL researchers are investigating ways to mimic these exquisite molecular architectures to develop synthetic, bio-inspired systems for the conversion of solar energy to electricity and fuel.

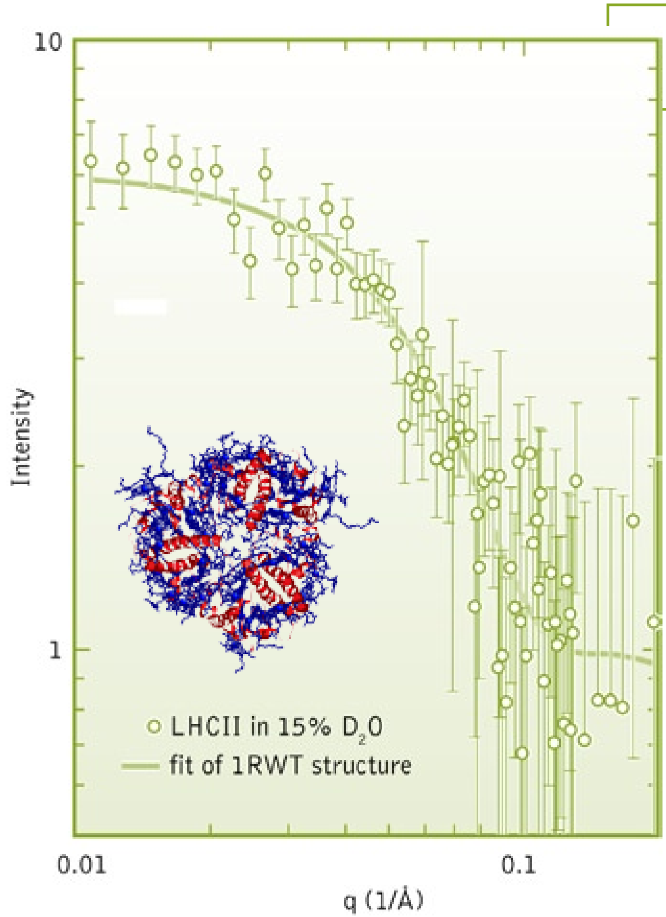
The ultimate goal, says principal investigator Hugh O'Neill of the Chemical Sciences Division (CSD), is to convert solar energy into electricity or fuel, thereby developing a competitive energy source. This goal is one of the key challenges outlined by the U.S. Department of Energy's (DOE's) 2005 Basic Energy Sciences Workshop report, Basic Research Needs for Solar Energy Utilization." The researchers hope the results of the work will lay the foundation for future photovoltaic devices, which combine the elements of naturally occurring photosynthetic systems of plants with functional polymers whose morphology can be engineered to take on desired forms.

The interdisciplinary research team consists of ORNL staff Hugh O'Neill, William Heller, Dmitriy Smolensky, and Mateus Cardoso (CSD and the Center for Structural Biology); Kunlun Hong and Xiang Yu (CSD and Center for Nanophase Materials Sciences, CNMS); and Bernard Kippelen (School of Electrical and Computer Engineering, Georgia Institute of Technology). For their research, the team uses the Bio-SANS (CG-3) instrument at HFIR. This instrument is designed for small-angle neutron scattering (SANS) studies and is optimized for investigating the structure and dynamics of proteins, polymers, colloids, and viruses. The functional polymers used in the research are synthesized and characterized in collaboration with CNMS.

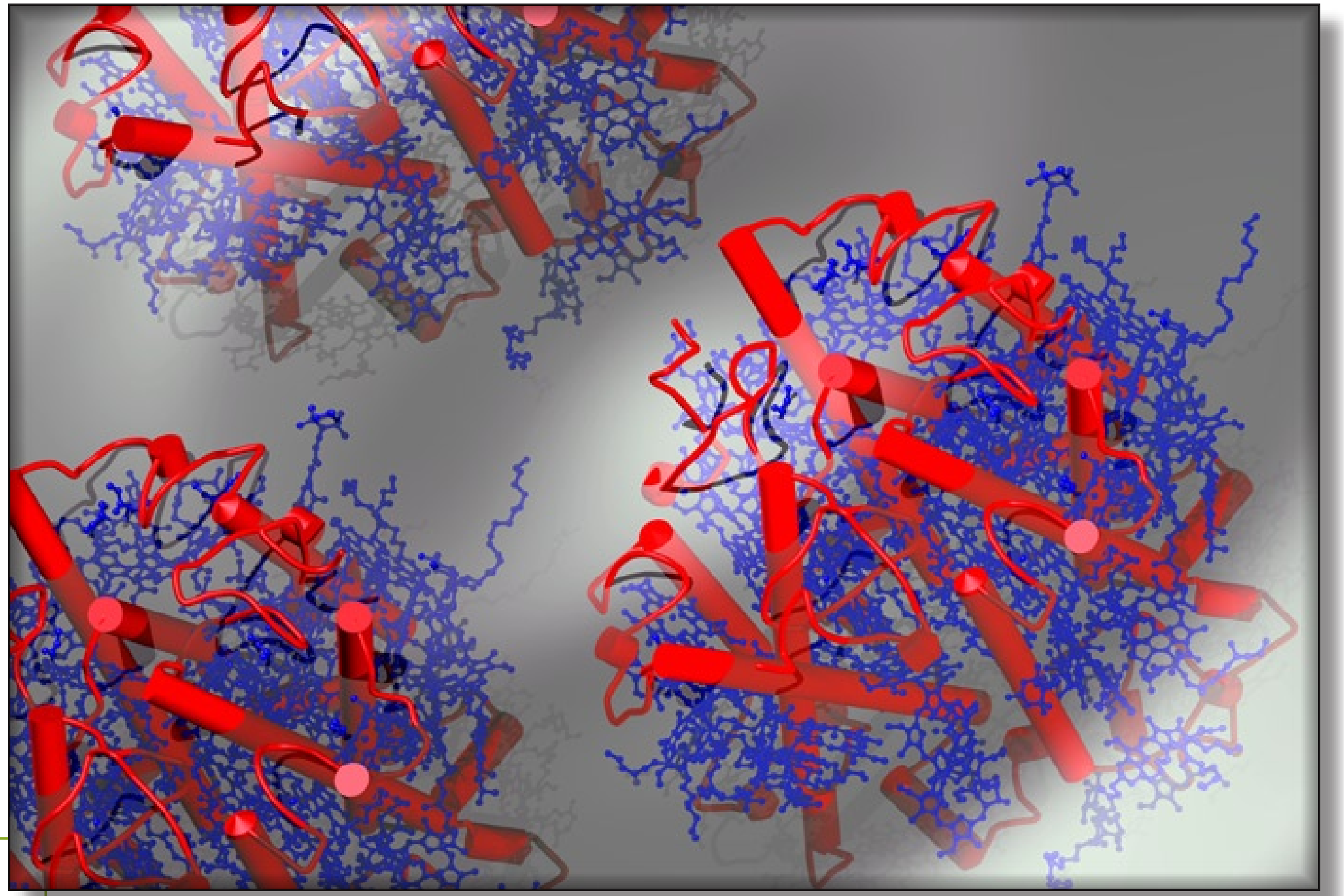
Much of the team's research involves studies of light harvesting complex II (LHC II), a protein complex that is responsible for light capture in plants. SANS experiments were performed with LHC II in detergent solutions containing mixtures of hydrogenated and deuterated water (D_2O). Control of the D_2O concentration allows separate visualization of the protein and detergent, as well as the sample as a whole, through application of contrast variation methods. At the H_2O/D_2O mixture where the detergent is invisible (~15%), researchers could see the scattering profile of the protein, without any significant contribution by the detergent. This study showed that the protein was in its native trimeric state and provides preliminary data for the investigation of the interaction of the protein with synthetic polymer systems. Beginning in 2009, the group plans to use the Bio-SANS instrument for follow-on structural analysis studies of the polymer-protein systems.

"This fundamental research takes inspiration from nature, utilizing LHC II, and combines it with precision polymer synthesis to produce new photosynthetic systems that will potentially have properties that exceed current biosystems," said Phillip Britt, CSD director. "This project takes advantage of the unique properties of neutrons, which allow only the part of interest to be observed by contrast matching, to study the structure of protein complex in a nonnative environment. These studies will lay the foundation for understanding how the macromolecular structure, or more precisely the three-dimensional orientation of molecules in space, leads to the conversion of light into electricity and how to design new more efficient biohybrid systems."

In future work, the researchers will extend their research by developing synthetic versions of LHC II to replace the natural protein. It is envisioned that synthetic analogues of LHC II could be directly integrated into electroactive block copolymers to produce a self-assembled photovoltaic structure in a configuration that will respond optimally to light.



LHC II is the major chlorophyll binding protein in the photosynthetic membrane. This is the first investigation of its structure in solution.



Artistic rendition of LHC II in a polymer membrane.