



Mimicking bacterial photosynthetic structure for energy applications

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Team created a simple, synthetic analog of a bacterial antenna system used in photosynthesis

Collaborators from the Laboratory's Center for Integrated Nanotechnologies (MPA-CINT) and Sandia National Laboratories have demonstrated the ability of a short-chain block copolymer to self assemble into a 3-D supramolecular light-harvesting system. The work is a step toward mimicking photosynthetic bacteria, one of nature's best examples of optimizing both light harvesting and energy transfer. The team aims make a bio-inspired, simple analog for energy applications. [Nanoscale](#) published the research.

Significance of the work

The researchers used a short chain bio-inspired block copolymer to generate a simple, synthetic analog of a green bacterial antenna system used in photosynthesis. Green bacteria exploit a large supramolecular light-harvesting complex (called the chlorosome), which contains tens of thousands of self-organized pigments to create an optically dense light-harvesting structure. Lipids in the native green bacterial systems act as a scaffolding to create the appropriate environment for chlorosome assembly and function. A self-contained nanocomposite material that replicates such organization and functional response had not been achieved previously outside of the natural biosynthesis of chlorosomes in photosynthetic bacteria.

The team reasoned that a bio-inspired light-harvesting analog could be functionally efficient without copying the complex atomic level details of most natural bacterial antenna systems. The researchers demonstrated the inherent flexibility of a block copolymer to generate the scaffolding of a functional photosystem inspired by the unique organization found in green bacterial photosynthesis.

Unlike native green bacterial systems that use multiple lipids and proteins as a matrix to generate the necessary environment for chlorosome assembly and function, the artificial system matrix is much simpler. A single type of polymer amphiphile (molecule having a polar water-soluble group attached to a water-insoluble hydrocarbon chain) and a pigment from green bacteria—bacteriochlorophyll c—comprise the bio-inspired system. A hydrophobic pocket created during processing enables bacteriochlorophyll c organization in the polymer chlorosome nanocomposites. These structures demonstrate

the first 3-D mesoscopic structural mimic of natural chlorosomes in shape and aspect ratio.

The long-range ordering of polymer chlorosome nanocomposites and the structural and optical similarities to native chlorosomes suggest that secondary components in native bacterial antenna systems are not necessary to induce chlorosome-like organization of bacteriochlorophyll c in artificial systems. The results suggest the minimal requirements to induce chlorosome-like organization and function and represent a potential advance in the design of scalable artificial photosynthetic systems for photonic applications.

Achievements

The research showed that the inherent flexibility and propensities of the block copolymer control the system assembly. The team prepared all materials through self-assembly and non-covalent interactions of chromophores (light-absorbing molecules). The resulting highly modular polymer chlorosome nanocomposites possess physical and optical properties that can be tuned by switching or adding different chromophores (e.g., bacteriochlorophyll c) and functionalized polymers.

The copolymer exhibits flexibility as a membrane material and enables generation of mimics of 3-D chlorosomes as well as supported membrane bilayers containing energy acceptors. The ability of the polymer to adopt morphologies far from equilibrium allowed the appropriate environment for long-range bacteriochlorophyll c organization with mesoscopic structure similar to native chlorosomes. Supramolecular structures, called polymer–chlorosome nanocomposites (PCNs), physically and spectrally resembling natural chlorosomes were formed through self-assembly of bacteriochlorophyll c and the copolymer. These structures mimic the environment created by multiple green bacterial lipids and proteins for highly ordered aggregates of bacteriochlorophyll c. This result indicates a unique advantage of short-chain block copolymers as membrane materials to form simple structural analogs of biological materials.

The research team

Reference: “Amphiphilic Block Copolymers as Flexible Membrane Materials Generating Structural and Functional Mimics of Green Bacterial Antenna Complexes,” *Nanoscale* 8, 15056 (2016); doi: 10.1039/c6nr02497a.

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Caption for image below: Model organization in natural and nanocomposite systems. A) Natural chlorosome. B) Self-assembled nanocomposite.

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