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Improved Organic Semiconductors and Organic Photovoltaics

Background

Traditionally, photosensitive optoelectronic devices such as solar cells have been constructed of a number of inorganic semiconductors. Purity and crystalline grain size are a large determinant of efficiency in these cells. The smaller the grains and the more impure the material, the lower the efficiency. The drawback to using these typical inorganic photovoltaic (PV) materials is that processing is often quite expensive and energy intensive. Pure monocrystalline silicon, currently a common material used in PV production, requires rigorous purification and a very slow cooling from a melt. Other methods require techniques like vapor deposition, which needs expensive vacuum chambers.

Technology

A group of researchers at the University of Colorado led by David Walba and Noel Clark have uncovered the highly complex structure of a new Liquid Crystal phase called the B4 phase, which has potential for use as an organic semiconductor. This invention improves upon existing organic photovoltaic (OPV) materials used to convert solar energy into electricity with inexpensive organic materials. Many different B4 OPV molecules can be designed, and can be used as organic semiconductors. In general, the B4 phase is composed of organic crystalline (or hexatic) layers, which spontaneously self-assemble into nanorods. The B4 nanorod system is well suited for molecular electronics applications, with expected high carrier mobilities along and across the rods. Furthermore, macroscopic alignment of the rods (as for most liquid crystals) is possible, enhancing their potential for molecular electronics applications.

Advantages

LC phases composed of organic crystalline nanorods have the potential for carrier mobilities much higher than with polycrystalline or amorphous polymers currently in use. Also, the radius of the rods (~ 30 nm), combined with the fact that B4 easily entrains many other materials, makes B4 highly attractive for formation of bulk heterojunction composites. The additional supramolecular control of structure deriving from the alignability of the LC nanorods is also a key advantage. In general, organic semiconductors have several advantages over inorganic semiconductors, many of which are based on the ease of the processing required and low cost. Organic materials can also be used for flexible lightweight solar cells, allowing for their use in applications where inorganic materials are unsuitable. Rare elements present in inorganics such as indium are not needed for organic materials, dramatically lowering material costs. Another problem that can be easily solved through the Liquid Crystal phase is the appearance of defects in semiconductors. In a solid phase, expensive purification techniques would be needed to solve the defects. However, if a semiconducting material can be heated into a low viscosity liquid crystalline phase, it can provide a nanostructure with few defects and with desired orientational control.

Key Documents

"Improved Organic Photovoltaics." Provisional patent application filed February 10, 2011; available under CDA.

Spontaneous Ferroelectric Order in a Bent-Core Smectic Liquid Crystal of Fluid Orthorhombic Layers. Science. 2011 April 1; 72-77. *PDF available upon request*

Helical Nanofilament Phases. Science. 2009 Jul 24; 456-460. *PDF available upon request*

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