

Transparent PV Technologies

Background

New generation solar cells are emerging with a growing demand for less energy-intensive processing. Organic photovoltaics (OPV) are a promising candidate for low-cost, highly efficient solar energy harvesting. Moreover, these polymers form transparent photovoltaics, which are of interest in building-integrated photovoltaics that simultaneously serve as a building material and clean energy source. These polymers are attractive absorbing materials for building-integrated devices because of their low cost, ease of processing, mechanical flexibility, and transparency. However, current technologies that achieve high visible transparency from 400 nm – 650 nm have low power conversion efficiencies (PCE <4%) and poor device performance. Thus, improvements to the efficiencies and to the visible transmission (>30%) of transparent and semi-transparent OPV devices are in high demand for next generation solar cells.

One technique for PCE improvement is adopting a tandem architecture, which uses multi-junction solar cells to harness a broader range of the solar spectrum. While this design is typically implemented in III-V semiconductors to achieve ~30% efficiencies, their high fabrication costs hinder mass commercialization. Therefore, applying tandem architectures to solution-processed OPVs could provide a pathway for improved PCEs at commercially viable costs.

These commercially viable processing costs are further realized through solution-processing the OPV's top transparent conductor layer. Indium-Tin-Oxide (ITO) is the most widely used transparent conductive film on the market because it provides high transparency and low sheet resistance. However, the increased demand and low availability of natural indium sources has created a need to develop other transparent conductive electrode technologies. Moreover, ITO is typically fabricated through costly vacuum deposition techniques. Solution-processed silver nanowire (AgNW) networks achieve a viable transparent conductor with comparable performance to ITO. Thus, AgNW are an attractive candidate for solution-processed OPV transparent conductors. Solution processing methods, along with improvements in performance, would allow the organic-based optoelectronic devices to be competitive alternatives to traditional silicon and other inorganic technologies



Novel Polymers for Polymer Solar Cells, Transistors, and Sensors

This invention presents a novel class of conjugated polymers with low bandgaps (1.4 eV-1.5 eV). These polymer materials have a tunable structure and electronic properties, thereby allowing this material to fit into a variety of applications. Implementing these unique polymers into tandem solar cell devices has resulted in power conversion efficiencies as high as 9.5%, which show excellent stability and reproducibility. These devices have better charge transport properties than other similar materials, giving rise to higher open circuit voltage and short circuit current. With optimization, there is a possibility of achieving 15% efficiency.

Reference: UCLA Case No. 2011-558

US Patent 9,425,420

A Solution Method to Improve Nanowires Connection and its Applications in Electro-Related Areas

This invention demonstrates a solution-based method to achieve highly conductive silver nanowire (AgNW) mesh composite films with high transparency and excellent mechanical, electrical and optical properties. The method improves connections between nanowires to form a continuous network and thus greatly enhances the electrical performance of nanowire meshes. The nanowire precursor is readily available unlike indium tin oxide (ITO), the most commonly used transparent conductor material, which has a low availability of natural indium sources.

Reference: UCLA Case No. 2012-112

US Patent 9,460,999

Silver Nanowire-Indium Tin Oxide Nanoparticles as a Transparent Conductor for Optoelectronic Devices

This invention is a novel indium tin oxide (ITO) NP-AgNW composite thin film for transparent, flexible optoelectronic devices. This low temperature technique shows improved wire-to-wire junction conductance, smooth surface morphology, excellent mechanical adhesion and flexibility while maintaining the sheet resistance and transmittance values necessary to replace conventional sputtered ITO thin films. As a proof of concept, ITO NPs were embedded into a AgNW mesh, but this method can be further extended to other metal oxide NPs that are less expensive and more abundant, like aluminum doped zinc oxide and antimony doped tin oxide. This will result in a wide range of conductive metal oxide materials for use in a variety of optoelectronic devices.

Reference: UCLA Case No. 2012-113



US Patent 9,560,754

Design of Semi-Transparent, Transparent, Stacked or Top-Illuminated Organic Photovoltaic Devices

This invention demonstrates novel tandem solar cell devices that are visibly transparent or semi-transparent with efficiencies of 6.4% or 7%, respectively. At 550 nm, these solar cells have a maximum transmission of 51% for transparent OPVs and 30% for semi-transparent OPV devices. These unique solar cells are fabricated in a low temperature, solution processable, and cost-effective manner and results in mechanically flexible and lightweight devices. This technology will have applications as building materials and power generators, while maintaining an attractive building exterior or adding structural accents in future architectural designs.

Reference: UCLA Case No. 2012-792

US Patent 8,993,998

Organic Tandem Photovoltaic Devices Connected by Solution Processed Inorganic Metal and Metal Oxide

This invention is an inorganic-based interconnecting layer for organic tandem solar cells with superior device performance and stability. The entire solar cell is compatible with readily scalable solution processing techniques, including roll-to-roll. The all-solution processed organic tandem solar cell is cost effective and compatible with processing for flexible electronic applications. Moreover, because of their high transparency, the metal and metal oxide nanoparticle interconnecting layer can be used in transparent electronic applications.

Reference: UCLA Case No. 2013-261

US Provisional Patent Application 61/799,156

Transparent Organic Solar Cells For Agronomic Applications

This invention discloses a novel solar cell that has a power conversion efficiency of ~5%, using mainly solar light from the near-IR region (700 nm – 900 nm), and is transparent between 400 nm to 700 nm, with minimal reduction of the solar spectrum. This TOPV can be combined with other types of semitransparent solar cells, down conversion materials, or transparent organic light emitting diodes to enhance its efficiency for applications where only certain regions of the visible spectrum are required by the plants.



This technology will have applications in the field of agriculture to generate clean energy from the sun while optimizing plant growth.

Reference: UCLA Case No. 2013-515

US Provisional Patent Application 61/768,979

Multiple Donor/Acceptor Bulk Heterojunction Solar Cells

This invention demonstrates a new device structure for organic photovoltaics that expands the absorption bandwidth and increases overall device performance of the organic solar cells. In contrast to multiple junction solar cells, the approach does not require further fabrication steps, thereby mitigating increases in manufacturing cost and complexity.

Reference: UCLA Case No. 2013-919

US Provisional Patent Application 61/881,265

Potential Applications

- Grid solar cells
- Portable solar cells
- LEDs
- Field-effect transistors
- Wearable electronics
- Agronomics

Advantages

- High performance electronic devices, including solar cells with 10% efficiency
- Solution processable – low-cost and versatile manufacturing
- Uses inexpensive, well-studied materials for many layers
- May use a variety of substrates, including flexible plastics
- Tandem structures expand the absorption bandwidth, which increases the solar cell efficiency
- IR absorbing polymers form visibly transparent or semi-transparent solar cells
- Technique applicable to a range of substrates and devices including flexible films, multi-junction solar cells, LEDs, sensors and superconductors



Development-to-Date

Prototype polymer-based solar cell devices have been fabricated with efficiencies of 10%, which hold the world-record efficiency according to the National Renewable Energy Lab.

Biography

Yang Yang is the Carol and Lawrence E. Tannas Jr. Chair in Engineering and a Professor of Materials Science and Engineering at the UCLA Henry Samueli School of Engineering and Applied Science. His notable contributions to the field of organic photovoltaics (OPV) include tandem solar cells, photovoltaic polarizers for LCD applications, and transparent OPV devices. Moreover, his collaborations have resulted in several OPV devices with record-breaking efficiencies. In addition to record-breaking organic solar cells, his group also develops perovskite photovoltaics.

Professor Yang has been cited by Thomson Reuters IP and Science as one of the “World’s Most Influential Scientific Minds” and one of the world’s most highly cited researchers in chemistry and materials science. He is a fellow of the American Physical Society, the Materials Research Society, and the Royal Society of Chemistry. Yang, who joined the UCLA faculty in 1997, has more than 60 patents and has published more than 290 peer-reviewed papers. He received his Ph.D. in physics and applied physics from the University of Massachusetts Lowell.

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