WATERLOO INSTITUTE FOR NANOTECHNOLOGY

Yuning Li

Professor, Chemical Engineering

Research interests: molecular engineering of polymer/transparent semiconductors for organic electronics (OTFT, OPV, DSC, OLED) and low temp-process conductive inks on plastic substrates

Biography

Professor Yuning Li in the Department of Chemical Engineering is working on nanomaterials/electronic materials for organic electronic applications with emphases on following topics.

Education

- PhD, Polymer Materials, Japan Advanced Institute of Science and Technology (JAIST), Japan, 1999
- MS, Polymer Materials, Dalian University of Technology, China, 1988
- BS, Polymer Materials, Dalian University of Technology, China, 1985

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RESEARCH

Organic semiconductors for Organic Thin Film Transistors (OTFTs)

OTFTs are the fundamental building elements for many organic electronics, such as displays, Radio-Frequency Identification (RFID) tags, bio-/chemical sensors, etc. Most solution-processable organic semiconductors show poor electrical performance with charge carrier mobility of < 0.1 $cm^2/V.s$ in OTFTs, which severely limits their applications. Our group recently developed several new **p-type polymer semiconductors** with mobility of ~1 $cm^2/V.s$, which is among the highest reported for polymer semiconductors. Based on our recent results, it seems that there is still plenty room for improvement in terms of electrical performance for polymer semiconductors. Our research in this area will focus on the chemical and electronic structural design, molecular organization, fundamental understanding of the charge transport mechanism and application of high performance polymer semiconductors.

Until recently the majority of research efforts have been made on the development of unipolar p-type and n-type polymer semiconductors for OTFTs. However, for digital logic circuits that require high reliability, high noise immunity, and low power dissipation, Complementary-symmetry Metal–Oxide–Semiconductor (CMOS)-like device structures comprising complementary p-channel and n-channel transistors are preferred. Through a proper structural design, organic semiconductors can be amibipolar, i.e., conducting both electrons and holes, which are suitable for fabricating amibipolar OTFTs in CMOS-like circuits. Our group has developed high performance **ambipolar polymer semiconductors** which showed balanced high electron and hole mobilities of ~0.4 $cm^2/V.s$ in OTFTs. We will continue working on the design of ambipolar polymer semiconductors with higher mobilities and better air stability. We are also seeking collaborations with faculty members in the Electrical Engineering to work on the design, printing, and evaluation of digital circuits using our ambipolar polymers.

Semiconductors for Organic Photovoltaics (OPV)

OPV or organic solar cells are of great commercial interests due to their light weight, robustness, and ease of manufacturing. Two types of organic solar cells have been mostly investigated: bulk-heterojunction (BHJ) cells and dye-sensitized cells (DSC). Currently, low efficiency and poor stability of OPV devices hinder their applications. Prof. Li’s group is currently focusing on the following aspects.

- Materials development
    - P-type polymers with optimum band gaps (1.2-1.7 eV) for maximum light harvesting and optimum energy levels to minimize energy losses
    - Novel n-type semiconductors
- Light management

    - Plasmonic enhancement using metal nanoparticles, which can potentially increase the power conversion efficiency by 30-40%

- Nanophase separation control
    - Prescribed nanophase-separated donor-acceptor architectures using nanomaterials versus the conventional uncontrollable/unstable nanophase separation structures obtained through passive molecular self-assembly techniques

- Low temperature processed DSC
    - Low-temperature, solution processed mesoporous photoconductors (e.g., nanocrystalline TiO_2, ZnO), which enables the use of flexible plastic substrates
    - Low band gap organic dyes to improve light harvesting

Printable conductors for various electronics

Conductive elements are required for almost all electronics. Nanoparticle-based conductive inks are particularly useful for printed organic electronics, since nanoparticles of < ~100 nm can be co-alesced into conductive films at a low temperature of <200 °C, which is compatible to the plastic substrates and organic semiconductors. Prof. Li has invented and co-invented several metal nano-particle-based conductive inks and one of them has been commercialized by Xerox (the "Silver Bullet" ink). Our group will apply this nanotechnology one step further to the following applica-tions.

- Low temperature nanoparticle-based conductive inks for printing transparent electrodes for organic solar cells
- Low cost nanoparticle-based conductive inks without using expensive Au or Ag for ubiquitous electronics

PUBLICATIONS

CONTACT