PHYS.ORG

High-performance, organic nanowire phototransistors open the way for optoelectronic device miniaturization

March 12 2013

A research team from Ulsan National Institute of Science and Technology (UNIST), South Korea has developed high-performance organic phototransistors (OPTs) based on single-crystalline n-channel organic nanowires. The research was published recently in *Advanced Functional Materials*.

Phototransistors are transistors in which the incident light intensity can modulate the charge-carrier density in the channel. Compared with conventional photodiodes, phototransistors enable easier control of light-detection sensitivity without problems such as the noise increment. However, to date, the research has mostly focused on thin-film OPTs, and nanoscale OPTs have scarcely been reported.

OPTs have many intrinsic advantages over their inorganic counterparts, such as the chemical tunability of optoelectronic properties by molecular design and high potential in low cost, light-weight, flexible applications.

Single-crystalline nano-/microwires (NWs/MWs) based on organic semiconductors have attracted great interest recently as they are promising building blocks for various electronic and optoelectronic applications. In particular, OPTs based on single-crystalline NWs/MWs may yield higher light sensitivity than their bulk counterparts. In addition, their one-dimensional, intrinsically defect-free and highly ordered nature will allow a deeper understanding of the fundamental mechanisms of charge generation and transport in OPTs, while enabling a bottom-up fabrication of optoelectronic nanodevices.

Prof. Joon Hak Oh and Hojeong Yu, working at UNIST, together with Prof. Zhenan Bao at Stanford University, USA, have worked on n-channel single-crystalline nanowire organic phototransistors (NW-OPTs) and observed significant enhancement in the charge-carrier mobility of NW-OPTs.

Prof. Oh said, "The development of OPTs based on n-channel single-crystalline organic semiconducting NWs/MWs is highly desirable for the bottom-up fabrication of complementary metal oxide semiconductor (CMOS)-like photoelectronic circuits, which provides various advantages such as high operational stability, easy control of photoswitching voltages, high photosensitivity and responsivity."

The photoelectronic characteristics of the single-crystalline NW-OPTs such as the photoresponsivity, the photo-switching ratio, and the photoconductive gain, were analyzed from the I-V characteristics coupled with light irradiation and compared with those of vacuum-deposited thin-film devices. The external quantum efficiencies (EQEs) were also investigated for the NW-OPTs and thin-film OPTs. In addition, they calculated the charge accumulation and release rates from deep traps, and investigated the effects of incident light intensity on their photoelectronic properties.

A mobility enhancement is observed when the incident optical power density increases and the wavelength of the light source matches the light-absorption range of the photoactive material. The photoswitching ratio is strongly dependent upon the incident optical power density, whereas the photoresponsivity is more dependent on matching the light-source wavelength with the maximum absorption range of the photoactive material.

NW-OPTs based on n-channel semiconductor, N,N ′-bis(2-phenylethyl)-perylene-3,4:9,10-tetracarboxylic diimide (BPE-PTCDI), exhibited much higher external quantum efficiency (EQE) values (≈7900 times larger) than thin-film OPTs, with a maximum EQE of 263 000%. This phenomena resulted from the intrinsically defect-free single-crystalline nature of the BPE-PTCDI NWs. In addition, an approach was devised to analyze the charge-transport behaviors using charge accumulation/release rates from deep traps under on/off switching of external light sources.

"Our approach to charge-accumulation/release-rate calculations could provide a fundamental understanding about charge-carrier-density variations under light irradiation, which subsequently enables in-depth study of OPTs," said Prof. Oh, "Hence organic single-crystalline NW-OPTs are a highly promising alternative to conventional thin-film-type photodiodes, and can effectively pave the way for optoelectronic device miniaturization."

More information: The article can be found at onlinelibrary.wiley.com/doi/10 … m.201201848/abstract

Provided by Ulsan National Institute of Science and Technology

Citation: High-performance, organic nanowire phototransistors open the way for optoelectronic device miniaturization (2013, March 12) retrieved 19 April 2024 from https://phys.org/news/2013-03-high-performance-nanowire-phototransistors-optoelectronic-device.html

This document is subject to copyright. Apart from any fair dealing for the purpose of private study or research, no part may be reproduced without the written permission. The content is provided for information purposes only.