고성능 전계 트랜지스터 및 광 트랜지스터 응용을 위한 고분자 나노와이어 개발

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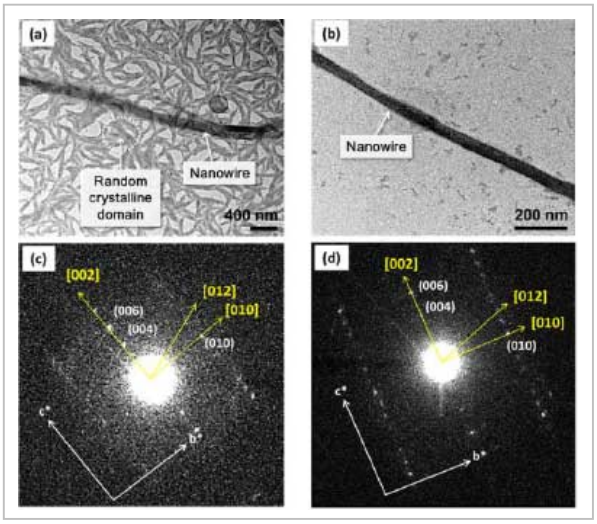
연구내용

투과전자현미경(TEM;Transmission Electron Microscopy) Low Dose 영상법을 이용하여 고분자 나노와이어 트랜지스터 특성을 규명하였음. 고려대 최동훈 교수 연구팀과의 공동연구를 통해 평면성을 지닌 DPP 기반의 고결정 고분자 DPPBTSPE(1,2-bis(5-(thiophen-2-yl)selenophen- 2-yl)ethene)을 합성하였고 Soxhlet 추출법을 이용 하여 분자량이 68 kDa과 8 kDa에 해당하는 두 종 의 고분자를 얻음. 분자량에 따른 박막 특성을 관 찰하고, 단결정 고분자 나노와이어(SC-PNW) 트랜 지스터를 형성하여 내재적 특성을 확인하였으며, 8 kDa의 고분자인 SC-PNW가 높은 종횡비를 가지며 π-π 적층방향이 나노 와이어 성장방향과 수직임을 규명하였음. 나노와이어 전계효과 트랜지스터 구 현 시 24 $cm^2 V^{-1}s^{-1}$의 높은 전하 이동도를 보였 으며 광트랜지스터 적용 시 평균광감응성 (R) 및 최대 광감응성 (R) 은 각각 160-170 A W^{-1}과 1920 A W^{-1}으로 박막 기반의 광 트랜지스터보다 약 1000배 높은 특성을 보임.



[그림 1] (a, b) PNWs TEM 영상, (a) high- and (b) low-MW DPPBTSPE. (C, d) Low Dose 영상법을 이용한 PNWs 의 SAED patterns, (c) high- and (d)low-MW DPPBTSPE.

기대효과

분자 나노와이어를 이용한 트랜지스터, 광 트랜지스터의 개발 및 제품화

ARTICLE

High Aspect Ratio Conjugated Polymer Nanowires for High Performance Field-Effect Transistors and Phototransistors

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ABSTRACT We synthesized a highly crystalline DPP-based polymer, DPPBTSPE, which contained 1,2-bis(5-(thiophen-2-yl)selenophen-2-yl)ethene as a planar and rigid electron donating group. High- and low-molecular weight (MW) DPPBTSPE fractions were collected by Soxhlet extraction and were employed to investigate their unique charge transport properties in macroscopic films and single crystalline polymer nanowire (SC-PNW), respectively. The low-MW polymer could provide well-isolated and high aspect ratio SC-PNWs, in which the direction of π−π stacking was perpendicular to the wire growing axis. The field effect transistors made of SC-PNWs exhibited remarkably high carrier mobility of 24 $cm^2 V^{-1} s^{-1}$. In addition, phototransistors (PTs) made of SC-PNW showed very high performance in terms of photoresponsivity (R) and photosensitivity (P). The average R of the SC-PNW-based PTs were in the range of 160−170 A W^{-1} and the maximum R was measured at 1920 A W^{-1}, which is almost three orders higher than that of thin film-based PT device.

KEYWORDS: diketopyrrolopyrrole · selenophene · polymer nanowire · field-effect transistor · phototransistor

Past research on organic semiconductors predominantly focused on *p*-type small molecules such as the polyacene, fused thiophene, and thienoacene derivatives. Field effect transistors (FETs) using these organic semiconductors demonstrated carrier mobility as superb as 20−40 $cm^2 V^{-1} s^{-1}$, thereby earning these semiconductors a reputation as materials that could replace inorganic semiconductors.[1] It was further observed that single-crystal and polycrystalline devices using organic semiconductors' microplates, microribbons, nanofibers, nanoribbons, etc., exhibited superior carrier mobility compared to that of the thin film-based FETs[2−10] In addition to outstanding charge transport behavior, photoinduced charge generation of organic semiconductors also have great attention in promising optoelectronic devices such as phototransistors (PTs) owing to their high photosensitivity and photoinduced modulation of electrical property.[10−12]

Until recently, the charge transport properties of semiconducting polymers have generally been recognized as inferior to those of semiconducting small molecules because of their chain disorder in the solid state. However, certain polymers are increasingly drawing attention for their high performance in field-effect transistors (FETs),[13−15] phototransistors (PTs)[16,17] and photovoltaic devices.[18,19]

Further, rapid progress has been achieved in the development of high performance semiconducting polymers with highly extended π-conjugation systems, and highly crystalline polymers have come to be accepted as suitable materials for the active channels in large-scale thin-film transistor (TFT) devices.[20−22] In particular, the use of the donor−acceptor (D−A) concept to create an alternating semiconducting copolymer structure has been demonstrated as a highly efficient strategy for improving semiconductor performance. In these structures, conjugated electron-donor and acceptor units are employed to reduce the bandgap energies[23] and the π−π stacking distance between polymer chains (<3.8 Å).[24,25] Because of these properties, D−A polymers

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