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Abstracts

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Fine Characteristic Manipulation of Organic Nanostructures: Applications to Optical and Bio Sensing

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1. Introduction

π-Conjugated organic semiconductors and their various nanostructures show considerable interesting optical and electrical properties due to intrinsic one-dimensional (1-D) characteristics.[1] For fundamental study and industrial application of optoelectronic nano-devices, it is important to control the physical properties of organic materials as well as to fabricate their nanostructures. We have investigated the effects of the unfocused electron (E)-beam irradiation onto the π-conjugated polymer nanomaterials, such as light-emitting poly (3-methylthiophene) (P3MT) nanotubes (NTs) and conducting polypyrrole (PPy) nanowires (NWs). The optical and electrical properties of the π-conjugated polymer nanomaterials were successfully modified with respect to the E-beam irradiating conditions, which were attributed to the dedoping effects and conformational modifications of the polymers (Fig. 1).[2,3] Recently, we reported on the light-emitting color barcode (LECB) NWs, fabricated by alternating the electrochemical polymerization of π-conjugated polymers with various luminescence colors and efficiencies. The alternating light emissions of the LECB-NWs showed orange-yellow, red, and green colors due to the serial combination of poly(3-butylthiophene) (P3BT), P3MT, and poly (3,4-ethylenedioxythiophene) (PEDOT), respectively, with distinct luminescence intensities (Fig. 2).[4] The optical detection sensitivity and stability of LECB NWs have been enhanced through a nanoscale Cu metal coating onto the NWs, based on surface plasmon resonance coupling and protection against oxidation, as shown in Fig. 2 (b).[4,5]

We report on the effect of the focused E-beam irradiation onto a single strand of P3MT and PPy NW, and successful fabrication of the 1-D superlattice NW through the focused E-beam treatment. We also present the DNA sensing by using a P3MT single NW, as a bio-related application. The variation of the structural and optical properties of P3MT single NW due to the DNA hybridization was investigated.

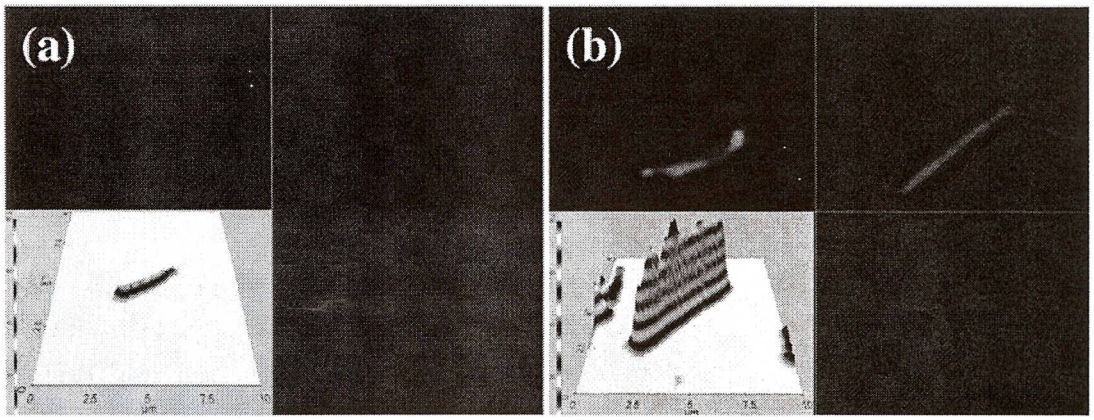

Fig. 1. Color charge-coupled device (CCD) images of (a) pristine P3MT NT and (b) unfocused E-beam treated P3MT NT (1 MeV, 8.0×10^{16} electrons/cm^2). Insets: Three-dimensional (3-D) laser confocal microscope (LCM) photoluminescence (PL) images.[2]

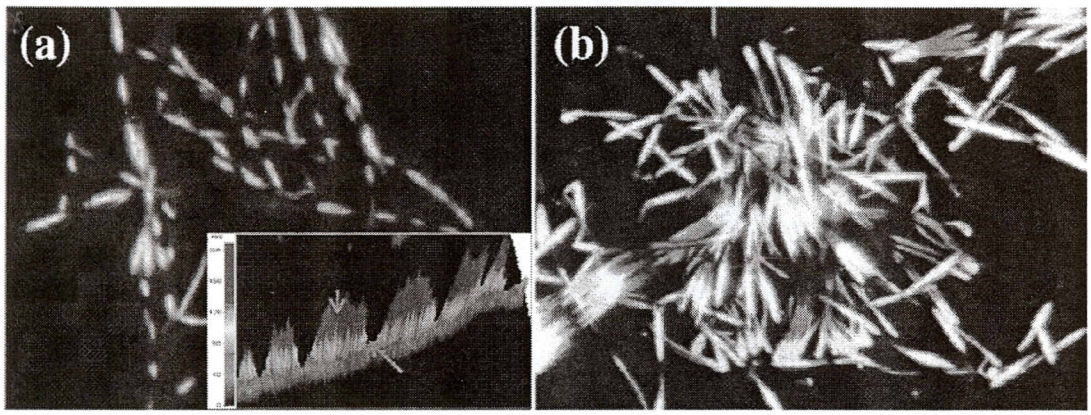

Fig. 2. (a) Color CCD image of dispersed P3BT-PEDOT LECB-NWs. Inset: 3-D LCM PL image of a single strand of P3BT-PEDOT LECB-NW. (b) Color CCD image of a bundle of the one year aged P3BT-PEDOT/Cu LECB-NWs. Excitation wavelength (λ_{ex}) was fixed to 430 nm.[4]

2. Result and Discussion

Light-emitting P3MT and conducting PPy NWs were synthesized through the electrochemical polymerization method by using nanoporous alumina template.[1-3] The focused E-beam, generated from the conventional E-beam lithography instrument, was irradiated on the designated positions of a single strand of the polymer NW, normal to length direction. The focused E-beam treated P3MT and PPy single NW were linear combination of 1-D serial multi-compartments with distinct lengths and characteristics. The charge transport mechanism of the focused E-beam treated PPy NW was investigated through the temperature dependence of current-voltage characteristics.

The probe DNAs (*p*-DNAs) were easily attached to the P3MT NWs through electrostatic interaction between the negative counter-ions and the terminal amine (NH_3^+) group attached at the end of the *p*-DNA. After the functionalization of *p*-DNA and their label-free recognition of target DNAs (*t*-DNAs) onto the surface of P3MT NWs, the light-emitting color and intensity of a P3MT single NW were dramatically changed. We observed color change of a P3MT single NW from green to red after attaching the *p*-DNA, and then luminescence intensity of a single P3MT/*p*-DNA NW was dramatically enhanced by hybridizing *t*-DNA. The enhanced PL of the P3MT/*p*-DNA+ *t*-DNA can be explained in terms of the dopant-mediated fluorescence chain reaction.

3. References

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