Optoelectronic Applications Using Hybrids of Quantum Dots and Organic Semiconductors

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1. Introduction

Light-emitting quantum dots (QDs) have been used for various optoelectronic devices and bio-sensors [1] due to tunable band gap and bright light emission. Nanoscale organic semiconductors have been utilized for heterojunction photovoltaic devices and light-emitting diodes. The hybridization of the QDs with p-type organic semiconducting nanostructures induces energy and charge transfer effects, resulting in control of efficiency of optoelectronic and photonic devices [2]. For easy hybridization, QDs can be functionalized with various chemical ligands. Depending on the hybridization types between QDs and organic semiconductors, the energy and/or charge transfer effect can be optimized and applied to various devices. This study presents the results of multicolor optical waveguide and molecular optoelectronics using hybrids of QDs and organic semiconductors.

2. Results and Discussion

Multicolor optical waveguiding

Nanoscale multicolor optical waveguides have been demonstrated using a novel hybrids of highly crystalline blue-light-emitting organic 1,4-bis(3,5-bis(trifluoro methyl) styryl)-2,5-dibromobenzene (TSDB) nanowire (NW) combined with blue, green, and red CdSe/ZnS QDs [3]. The TSDB NWs were synthesized by self-assembled method in organic solution. The width and height of TSDB NWs were about 400 nm and 200 nm, respectively. The core–shell CdSe/ZnS QDs were passivated with 11-mercapto-1-undecanol functionalized terminal.

Emissions of QDs can be transferred and optically waveguided through highly packed π-conjugated organic TSDB molecules with different decay characteristics. Hybrid NWs of TSDB/G(green)-QDs/R(red)-QDs have shown a near white-color waveguiding with three constituent wavelengths centered at 488, 532, and 638 nm. These peaks cover the visible range, and the proportion of each color's component was calculated in terms of the CIE coordinates. The efficient waveguiding property of the hybrid NW system can be attributed to a strong coupling between QD excitons and propagated polaritons in the TSDB NW. We also observed the enhancement of the photoluminescence (PL) intensity for remote detection of Cy3 dye attached bio-materials by means of the waveguided QDs emissions and the efficient coupling of the QDs emission to the NW.

Molecular optoelectronics

Hybrids consisting of CdSe/ZnS QD as a core and p-type organic molecules as a shell were fabricated, and nanoscale PL and photoresponsive molecular electronic characteristics were investigated. The nanoscale PL characteristics for the single QD were drastically changed through close contact (~ 1.5 Å) with p-type polymers (P3000) owing to energy and charge transfer effects. However, for the hybrid QD-CB (carbazole) NP, the PL of the QD was dominant because of weak energy transfer resulting from the relatively longer insulating molecular block (~ 20 Å) between the QD and the CB molecule. The photocurrents of the single hybrid QD-P3000 NP were considerably higher and actively responded to both forward and reverse biases due to the energy and charge transfer effects, while those of the single QD-CB NP exhibited diode characteristics. And the photovoltaic behavior was observed from a single unit of QD-P3HT hybrid NPs with an intermediate insulating molecular block (~ 10 Å) (see Figure 1).

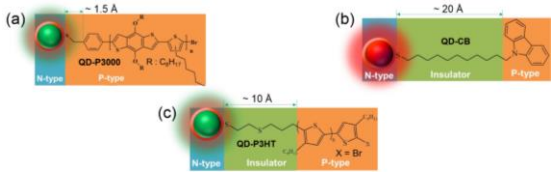

Figure 1. Schematic chemical structures of QDs-organic hybrids

3. Conclusions

Functional CdSe/ZnS QDs were hybridized with organic TSDB NWs, and the multicolor PL waveguiding and remote biosensing have been demonstrated through energy transfer effect. For different molecular level *n-p*-junctioned organic molecules and QD hybrids, the nanoscale PL and molecular optoelectronic properties were tuned by their relative distance and degree of spectral overlapping.

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