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Nonradiative Energy Transfer Between Colloidal Quantum-Dot Phosphors and Silicon Carbide Diodes

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Nonradiative energy transfer between colloidal quantum-dot (QD) phosphors and the active region of an indirect-bandgap semiconductor diode was investigated. A silicon carbide (SiC) *p–n* junction was fabricated and surface-patterned with arrays of holes, facilitating the sidewall coupling between the QDs and the SiC *p–n* junction. Nonradiative energy transfer was observed from the SiC diode to the colloidal QD phosphors, which was characterized with a color conversion efficiency of 3.1%. Time-resolved photoluminescence measurements were conducted to verify and characterize the energy transfer process between the diode and QDs. The carrier recombination lifetime of SiC was found to decrease upon the presence of QD phosphors, which provides further evidence for the presence of the nonradiative energy transfer path between the QDs and the SiC diode.

Key words: Quantum dot, energy transfer, phosphors

INTRODUCTION

The technology of white light-emitting diodes (LEDs) is playing a key role in solid-state lighting; most of the white LEDs currently in use employ blue emitters in combination with yellow phosphors to produce white light from the emission of complementary colors. However, such white output is inferior in "color rendering" ability to natural daylight, which is characterized by a low color rendering index (CRI). Colloidal compound quantum dots (QDs) have recently been introduced to white LED technology as a new family of phosphors due to their superior optical properties,[1–4] including high quantum yield, narrow emission bandwidth, and size-tunable emission wavelength over a broad spectral regime. Therefore, QDs of the same chemical composition, but varying sizes, can be employed as phosphors to provide multiple spectral components in white LED output.[5,6]

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The potential for use of QD phosphors has increased due to the recent discovery of a path for indirect injection of electron–hole pairs into QDs by noncontact, nonradiative energy transfer from the bulk junction of direct-bandgap semiconductors that are in close proximity to the nanoparticles.[7] When QDs are in the immediate vicinity of the carrier recombination region of the *p–n* junction of direct-bandgap semiconductors, there exists a unique relaxation path for the free carriers in the bulk semiconductor, transferring their energy into the QDs. This indirect, nonradiative energy path arises from the dipole–dipole interaction associated with the quantum coupling between QDs and direct-bandgap semiconductors.[7] In solid-state lighting, this newly uncovered pathway has been proposed to facilitate energy transfer from blue-emitting indium gallium nitride (InGaN) quantum wells into green and red CdSe/ZnS core–shell QD phosphors. The nonradiative energy transfer can potentially enhance the efficiency of the color conversion process because it removes several intermediate steps involved in the conventional multistep downconversion scheme,