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Mn^{2+}-Doped CdSe/CdS Core/Multishell Colloidal Quantum Wells Enabling Tunable Carrier–Dopant Exchange Interactions

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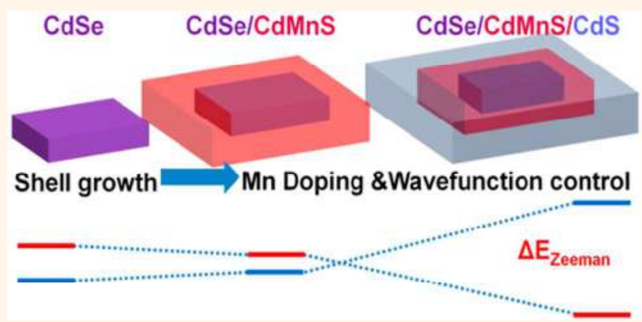
ABSTRACT In this work, we report the manifestations of carrier–dopant exchange interactions in colloidal Mn^{2+}-doped CdSe/CdS core/multishell quantum wells. The carrier–magnetic ion exchange interaction effects are tunable through wave function engineering. In our quantum well heterostructures, manganese was incorporated by growing a $Cd_{0.985}Mn_{0.015}S$ monolayer shell on undoped CdSe nanoplatelets using the colloidal atomic layer deposition technique. Unlike previously synthesized Mn^{2+}-doped colloidal nanostructures, the location of the Mn ions was controlled with atomic layer precision in our heterostructures. This is realized by controlling the spatial overlap between the carrier wave functions with the manganese ions by adjusting the location, composition, and number of the CdSe, $Cd_{1-x}Mn_xS$, and CdS layers. The photoluminescence quantum yield of our magnetic heterostructures was found to be as high as 20% at room temperature with a narrow photoluminescence bandwidth of ∼22 nm. Our colloidal quantum wells, which exhibit magneto-optical properties analogous to those of epitaxially grown quantum wells, offer new opportunities for solution-processed spin-based semiconductor devices.



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In diluted magnetic semiconductors (DMS), the incorporation of magnetic ions into a host semiconductor results in the appearance of extraordinary magnetic and optical properties.[1] The strong spin-exchange interactions between the carrier and magnetic ion spins result in these properties that can be harnessed for applications in spintronics, such as spin-polarized light-emitting diodes,[2] spin-transistors,[3] and spin-lasers.[4] Until recently, these devices have only been fabricated using molecular beam epitaxy (MBE); however, the use of colloidal nanocrystals doped with magnetic ions has attracted significant attention for these applications. Circularly polarized emission from Mn^{2+}-doped CdSe[5] and PbS[6] nanocrystals has been observed, and light-induced magnetization at room temperature has been demonstrated in $Cd_{1-x}Mn_xSe$ colloidal quantum dots (QDs).[7] In addition, the existence of carrier–dopant exchange interactions was demonstrated in Mn-doped CdSe nanoribbons.[8,9] The effects of carrier–magnetic ion spin-exchange interactions can be conveniently manipulated in core/shell heterostructures by controlling the carrier–ion wave function overlap.[10]

Colloidal quantum wells (QWs), also known as nanoplatelets (NPLs), have been synthesized recently with a thickness control at the monolayer (ML) level. This has been demonstrated in several systems including CdSe,[11,12] CdS,[13,14] and PbS.[15] Furthermore, core/shell (shell surrounding a NPL core) and

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