Photonic Crystal Architecture for Room-Temperature Equilibrium Bose-Einstein Condensation of Exciton Polaritons

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Abstract

We describe photonic crystal microcavities with very strong light-matter interaction to realize room-temperature, equilibrium, exciton-polariton Bose-Einstein condensation (BEC). This goal is achieved through a careful balance between strong light trapping in a photonic band gap (PBG) and large exciton density enabled by a multiple quantum-well (QW) structure with a moderate dielectric constant. This approach enables the formation of a long-lived, dense 10 - mu m - 1 - cm- scale cloud of exciton polaritons with vacuum Rabi splitting that is roughly 7% of the bare exciton-recombination energy. We introduce a woodpile photonic crystal made of Cd-0.6 Mg-0.4 Te with a 3D PBG of 9.2% (gap-to-central-frequency ratio) that strongly focuses a planar guided optical field on CdTe QWs in the cavity. For 3-nm QWs with 5-nm barrier width, the exciton-photon coupling can be as large as (h) over bar Omega = 55 meV (i.e., a vacuum Rabi splitting of 2 (h) over bar Omega = 110 meV). The exciton-recombination energy of 1.65 eV corresponds to an optical wavelength of 750 nm. For N = 106 QWs embedded in the cavity, the collective exciton-photon coupling per QW ((h) over bar Omega/root N = 5.4 meV) is much larger than the state-of-the-art value of 3.3 meV, for the CdTe Fabry-Perot microcavity. The maximum BEC temperature is limited by the depth of the dispersion minimum for the lower polariton branch, over which the polariton has a small effective mass of approximately 10(-5)m(0), where m(0) is the electron mass in vacuum. By detuning the bare exciton-recombination energy above the planar guided optical mode, a larger dispersion depth is achieved, enabling room-temperature BEC. The BEC transition temperature ranges as high as 500 K when the polariton density per QW is increased to (11a(B))(-2), where a(B) similar or equal to 3.5 nm is the exciton Bohr radius and the exciton-cavity detuning is increased to 30 meV. A high-quality PBG can suppress exciton radiative decay and enhance the polariton lifetime to beyond 150 ps at room temperature, sufficient for thermal equilibrium BEC.

Keywords

KeyWords Plus: CDTE/CDMGTE QUANTUM-WELLS; SEMICONDUCTOR MICROCAVITY; EMISSION; CDTE; ELECTRON; LIGHT; LASER; RECOMBINATION; INVERSION; BEHAVIOR

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