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Excitons: from excitations at surfaces to confinement in nanostructures

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Abstract

We present a review of optical properties of semiconductors capable of supporting excitons, that is, electron–hole pairs that form states bound by their mutual screened Coulomb attraction. We consider the interaction of light with surfaces, thin films, multilayered systems, small particles and rough surfaces accounting for excitonic transitions. The first part of the paper is devoted to studies done using classical electrodynamics within the nonlocal dielectric response theory. For the dielectric function we take the Hopfield and Thomas coupled harmonic oscillator model, which yields excitonic modes beyond the usual optical waves. Therefore, studies of the coupling of light to exciton–polaritons in the presence of surfaces require additional boundary conditions (ABCs) to determine the reflected and transmitted electromagnetic field amplitudes within models of abruptly terminated semiconductors. An alternative consisting in solving Maxwell's equations for the electromagnetic field together with an equation for the excitonic polarization derived from the quantum mechanical dynamics of electrons and holes, including a surface potential that accounts for the interaction of excitons with the surface is explored in the latter part of the paper. The surface potential may be modeled by an infinite barrier, or by smooth repulsive exponential potentials and Morse-type potential wells. Surface potential wells may produce entrapped excitonic states, which are explored at surfaces, films and superlattices. Scattering of light from non-ideal rough surfaces is also discussed. Comparison between theory and experiment is emphasized all along the paper.

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The final section is devoted to a microscopic theory which is ABC independent and explains the experimental measurements of transmission in thin films.

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