Electrical and Optical Properties of 1d-, 2d- and 3d-Dimensional Spherical Semiconductor Quantum Dots Superlattices

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Last decades physical properties of individual semiconductor quantum dots have been extensively studied both theoretically and experimentally. The effects of the size, shape, strain fields, and dielectric screening on electronic states and optical response of separated quantum dots (QD) are addressed in the literature in great detail. In a simplified picture, transport properties of arrays of weakly coupled quantum dots (its wave functions is well localized in a individual QD) are described in terms of hopping conduction, while optical response is defined by the energy spectrum of individual dots and inhomogeneous broadening due to the size distribution.

A more interesting and potentially practically important case is when strong coupling among dots leads to formation of 1D-, 2D- or 3D-dimensional extended minibands instead of localized quantum dot states. Regimented or partially regimented multiplearrays of quantum dots, also termed quantum dot superlattices, have already been fabricated by a variety of techniques. In these artificial crystals the role of atoms isplayed by quantum dots. Thus, we refer to these structures as quantum dot crystals or “supra crystals”. As a consequence, the energy spectrum of such supra crystals is characterized by emergence of minibands separated by complete stop bands. This situation observed at quantum dot superlattice.

Special optical and electric properties of this superlattices have already found their practical applications. For example, electrical conductivity perpendicular to the superlattice layers exhibits behaviour very similar to what is found in tunnel diode. Construction and properties of analogous device, based on quantum well structure fabricated from GaAs sandwiched between two $Ga_{1-x}Al_xAs$ barriers. The device could handle frequencies up to 2.5 THz, giving possibility to work at millimetre and submillimetre wavelengths.

In this paper we investigate the electron energy spectra in 1D-, 2D- and 3D-dimensional regimented GaAs/AlAs quantum dot superlattice by solving the Schrodinger equation in the envelope wave-function and strong coupling approximation. Electron densities of states, required for modeling of an electron transport and optical properties of quantum dot superlattices, were calculated. In addition, we obtained dependence of the electrical conductivity and Fermi energy on the temperature. Based on the results, it was found that the higher the temperature the more mini-bands are involved into the conduction process.