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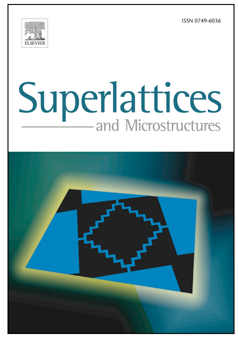

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Tunable excitonic transitions in strained GaAs ultra-thin quantum disk.

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Abstract

Simultaneous influences of hydrostatic pressure and temperature combined to the size effect on the behaviour of the exciton in 2D $AlAs/GaAs/AlAs$ ultra thin quantum disk are investigated. Our approach is performed in the framework of effective mass theory and adiabatic approximation by using a variational method with a robust trial wave function and by taking into account the dependence of the size, the dielectric constant and the effective masses on the pressure and temperature. Variations of the excitonic binding energy, photoluminescence energy and oscillator strength are determined according to hydrostatic pressure and temperature for different confinement regimes. The results of our numerical calculations show that the applied pressure favours the electron-hole attraction while the temperature tends to decrease the exciton binding energy. Another interesting result is the possibility of transforming a thin quantum disk into a large-gap material by strain effect. The opposing effects caused by temperature and pressure reveal a big practical interest and offer an alternative way to the tuning of the excitonic transition in optoelectronic devices.

Keywords: Exciton, Optical band gap, Pressure, Temperature, Oscillator strength.

1. Introduction

Since the extraordinary discoveries in graphene and recent advances in time-reversal invariant topological insulators, the emergence of the surface states and the engineering of two dimensional $(2D)$ nanomaterials currently attract considerable interest [1, 2]. These ultra thin nanomaterials with thickness on the atomic scale possess high flexibility and multifunctionality. Their fascinating physical properties promise new future applications opportunities and a great potential in optoelectronic applications in different domains mainly in spintronic and quantum computation [3, 4, 5, 6, 7, 8]. Recent studies demonstrated the possibility to drive the commonly used semiconductors into topological insulators states by using electrical or strain engineering [9, 10, 11, 12] instead of searching new chemical materials.

Generally speaking, the real shapes obtained by various growth techniques are probably much less symmetric than those used in theoretical models and some dots present a flattened shape considered as an almost bi-dimensional structure. Unfortunately, studies related to excitons or impurities in flat quantum dots are still rare compared to spherical and cylindrical quantum dots. Different theories and approaches are used in order to study this reduced geometry with or without external perturbations such as magnetic or electric fields [13, 14, 15, 16]. The most recent ones are our last studies where we have investigated the problems of excitons and donors in a thin quantum disk submitted to a lateral electric field [17, 18, 19].

In the last decade, the effects of temperature T and hydrostatic pressure P have attracted the intention of many authors. It has been established that in low dimensional structures, the binding energies of excitons and donors are enhanced with increasing pressure which compensates the instability caused by the temperature variation [20, 21, 22]. We recall some important results in various shapes: Oyoko et *al*. [23] have studied the effect of an uniaxial stress on the binding energy of a shallow donor impurity in parallelepipedic shaped $GaAs/GaAlAs$ quantum dot using a variational approach and taking into account the position of the ionized donor. Their conclusions are in good agreement with those obtained by Elabsy [22]. The effects of hydrostatic pressure and magnetic field on the optical