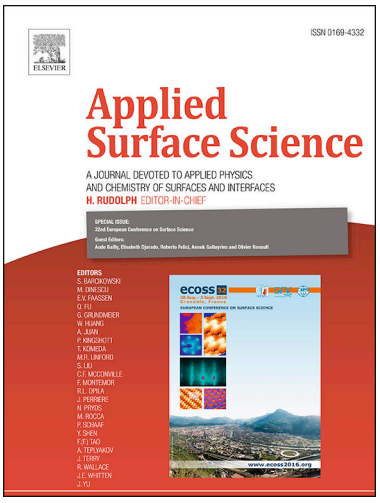

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Temperature and hydrostatic pressure effects on single dopant states in hollow cylindrical core-shell quantum dot

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This work reports on theoretical investigation of the temperature and hydrostatic pressure effects on the confined donor impurity in a AlGaAs-GaAs hollow cylindrical core-shell quantum dot. The charges are assumed to be completely confined to the interior of the shell with approximately rigid walls. Within the framework of the effective-mass approximation and by using a variational approach, we have computed the donor binding energies as a function of the shell size in order to study the behavior of the electron-impurity attraction for a very small thickness under the influence of both temperature and hydrostatic pressure. Our results show that the temperature and hydrostatic pressure have a significant influences on the impurity binding energy for large shell quantum dot. It will be shown that the binding energy is more pronounced with increasing pressure and decreasing temperature for any impurity position and quantum dot size. The photoionization cross section is also analyzed by considering only the in-plane incident radiation polarization. Its behavior is investigated as a function of photon energy for different values of pressure and temperature. The opposite effects caused by temperature and hydrostatic pressure reveal a big practical interest and offer an alternative way to tuning of correlated electron-impurity transitions in optoelectronic devices.

Keywords:
Temperature; Hydrostatic Pressure; Core-Shell; Quantum dots; Donor impurity; Binding energy; Photoionization cross section

I. INTRODUCTION

Core-shell nanoparticles (CSNs) are a new class of nanostructured materials that have recently received increased attention owing to their interesting properties and broad range of applications in bio-nanotechnology [1–3], enhanced optical devices [4–6], energy storage materials [7], electronic optical devices [8], materials chemistry and sensors by rationally tuning the cores as well as the shells of such materials [9]. The CSNs can be broadly defined as comprising a core (inner material) and a shell (outer layer material). Different classes of CSNs are synthesized. Concentric spherical CSNs are the most common where a simple spherical core particle is completely coated by a shell of a different material [10]. Other shaped CSNs have also given rise to immense research interest because of their different novel properties like hexagonal CSNs, movable core within hollow shell material, and cylindrical CSNs. Given the current status of core-shell nanocatalysis, a modern classification based on the shell properties of the materials would be beneficial, particularly for comparison of different synthetic strategies leading to varied shell properties. Broadly, these materials can be divided into three major categories [9]: hollow core-shell, core-multishell, and core- porous-shell.

So far, only a few of researches have focused on the theoretical study of cylindrical core-shell structures. For example, quadratic electro-optic effects in ZnS/CdSe/ZnS cylindrical nanoshells was investigated by Bahari et al [11]. They have shown that the structure size (shell thicknesses) is one of the main parameters which immediately influences the electroptical properties of materials. Theoretical study of the optical properties in ZnS/CdSe cylindrical quantum dot quantum well (QDQW) have been discussed by [12]. It has been shown that the optical properties depend on width of shell-well. In another side, the effects of confining potential and growth-direction applied magnetic field on the binding energy and photoionization cross section of a donor impurity in a cylindrical InAs quantum layer have been studied by Barseghyan et al [13]. Their numerical results have shown that the binding energy and the photoionization cross section (PCS) are changed with the change of the dimensions of the cylindrical InAs quantum layer. We conclude from these works that the core-shell size effects are responsible in what happens inside the nanoshells. During the growth process, it is possible intentionally or unintentionally to

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