Abstract of doctoral dissertation

Hole spin dynamics in semiconductor nanostructures

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The goal of this dissertation was analytical and numerical examination of selected topics regarding hole spin dynamics in semiconductor nanostructures InGaAs/InAs. In particular the object of the study were holes localized in single and double quantum dot systems. Inclusion of various effects due to crystal lattice deformation caused by material mismatch between quantum dot and bulk material proved crucial for the analysis of presented results.

The first of the presented studies was hole spin relaxation due to deformations in single quantum dots. Using proposed methodology the well known power laws concerning hole spin relaxation rates as a function of magnetic field magnitude were reproduced. It was shown that for the widely used range of magnetic fields used in the experimental research the dominant effects is caused by the coupling between hole states and phonon reservoir via phonon-induced piezoelectric field. Moreover, it was shown that the dominant contribution to the heavy hole band mixing necessary for the aforementioned effect is due to shear and biaxial deformation. In a special case of quantum hole with a strain-reducing layer the latter contribution is quenched, leading to a significant hole spin lifetime increase.

Next, the hole gyromagnetic factor in double quantum dots was considered in a function or various parameters, such as radius, height, indium concentration, elongation and axial shift of the quantum dots. It was proven that besides well knows tunnelling coupling between the quantum dots they interact via crystal lattice deformation caused by their presence. Crucial proved piezoelectric field penetrating to the other dot. It was predominantly shown in the case where only one of the quantum dots was varied and hole states were kept away from the tunnelling resonance using axial electric field — in such a case modification of one of the quantum dots heavily influenced gyromagnetic factor in the other. Further studies were conducted using varied electric and magnetic fields.

Lastly the coupling between hole states with an opposite spin localized in different quantum dots was studies. Such a coupling is possible only when the axial symmetry of the system is broken, either by quantum dot geometry (in this dissertation the cases of dot elongation and axial shift were considered) or electric field applied in the quantum dot plane. In order to study the influence of the symmetry break both analytically and quantitatively a measure of the asymmetry was proposed, calculated based off of the Hamiltonian describing the system. It was shown that with accordance to the physical intuition based on perturbation theory the coupling increases together with the asymmetry measure. In special cases it was shown that it is possible to compensate for the coupling due to symmetry breaking caused by one effect with a different one.