Acoustic and optical phonon emission rates in spherical quantum dots: magnetic effects

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In quantum dot systems, the role of the electron-phonon interaction on the carrier relaxation has been discussed paying attention to the possible slowing of relaxation rates due to the effects of confinement [1, 2]. The physics involved in the electron-phonon scattering process is still under discussion and problems related to *phonon bottleneck* and the contributing scattering channels require a more systematic discussion. In this work, we calculate the electron scattering rates due to coupling with acoustic and optical phonons in spherical quantum dots. The calculated scattering rates, via Fröhlich interaction, include the contributions of the confined and surface optical modes as obtained from the dielectric continuum model. Additionally, magnetic effects on the electron–LO-phonon scattering rates are also studied. The magnetic electron states are calculated within the strong-perturbation approximation. The effects of the competing contributions, due to magnetic and spatial confinements, on the scattering rates are studied. Our calculations show that the scattering rates are sensitive to the variation of the applied magnetic field and that more efficient scattering channels can be magnetically tuned in a wide range of dot radius by an appropriate choice of the strength of the field. These effects can be explained in terms of (i) the changes of the wavefunction symmetry which modifies the electron-phonon overlap and the selection rules for phonon emission, (ii) the interplay between the magnetic and spatial confinement and (iii) the additional quantization created by the magnetic field.

The acoustic modes are described in terms of the Lamb's classical theory of the oscillations of a continuous elastic sphere. The longitudinal spheroidal modes are included due their dominant contribution to the acoustic phonon deformation potential. We consider two mechanisms for electron-LA-phonon interaction: microscopic deformation potential (MDP) and the ripple mechanism (RM) [3], which results from the time varying modulations of the interface. The effects of the coupling of the phonons of the dot with those of the surrounding matrix are also discussed. For acoustic phonon emission, both the scattering rates due to MDP and RM decrease rapidly as functions of decreasing dot radius, and the rate from the RM coupling becomes dominant by more than two orders of magnitude for dot radii < 40 Å. This behaviour, in general, depends on the choice of the boundary conditions.

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