INTERFACE OPTICAL PHONONS IN SPHERICAL MULTILAYER NANOSTRUCTURES

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Research in semiconductor quantum dots (QDs) started with the realization that the optical and electronic properties of small semiconductor particles were strongly dependent on particle size, due to quantum confinement of the charge carriers in small spaces. A theoretical framework for these size-dependent properties was first described by Ekimov and Efros in 1982 [1, 2]. During the following two decades, intense research was carried out for potential applications in optoelectronic devices and high-density memories. Recently, two groups demostrated simultaneously that semiconductor QDs could be made water soluble and could be conjugated with biological molecules [3, 4]. Moreover, given the fact that the QD photoluminescence emission maximum can be manipulated by changing the particle size, their use as fluorescent labels for biological macromolecules has attracted considerable attention in medical imaging compared with conventional organic dyes. This new feature makes the semiconductor QDs object of intensive investigations in fundamental as well as applied aspects relative to their surfaces in order to get more feasible the conjugation with biological molecules [5, 6].

The aim of this work is to investigate the interface optical (IF) phonons in spherical QD heterostructures, systems modelled as follows: a spherical core of semiconductor “1” which is capped with a spherically concentric layer of semiconductor “2” and the whole structure is embedded in a hosted material considered as an infinite dielectric medium that does not participate of the polar optical vibrations. We use the dielectric continuum (DC) model, approach which is extensively applied to study phonon modes in semiconductor nanostructures [7]. The IF or surface optical (SO) phonons are associated to the crystal boundary surfaces and they are due to different dielectric constants at the interfaces. We determine for several III-V and II-VI semiconductor multilayer nanostructures the frequencies for the first excited IF modes. These modes with $l = 1, 2, 3$ are optically more active. Effect of the host islanding material on the IF frequency values is also investigated. To illustrate some of our results, we show in figure 1 the IF frequencies for CdS/ZnS QDs embedded in polyethylene as a function of the geometrical parameter γ (ratio of the shell to core radii) and $l = 1$. The two branches associated to ZnS-like modes as well as the CdS-like branch verify the resthralen criterium over the interval of γ investigated. All of them seem to be size independent for $\gamma > 2$, however for decreasing values of the geometrical parameter, noticeable dependences are observed.

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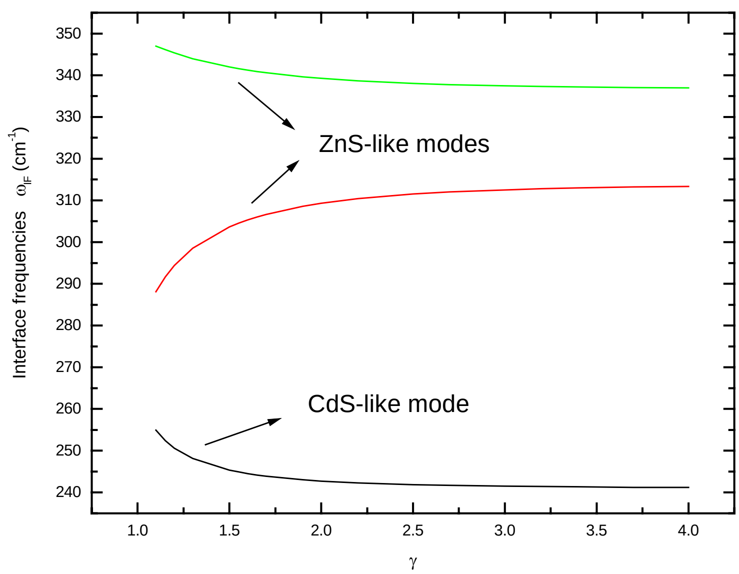

Figure 1. Interface frequencies (l=1) as a function of γ for spherical CdS/ZnS/polyethylene multilayer nanostrucutres; γ is a geometrical parameter defined as the ratio of the shell to core radii.