Type-II induced quantum confinement in type-I heterostructured semiconductor nanowires

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Abstract

Heterostructured semiconductor nanowires, one-dimensional quantum structures, are potential candidates for applications in nanoelectronics and photonic devices, such as transistors, light-emitting diodes, nanoscale lasers, thermoelectric, memory devices, among others [1]. Over the past years, the growth of core-shell [2], core-multishell [3], and longitudinal [4] nanowires composed of a variety of different semiconductor materials, since their chemistry is easily manipulated, have been reported in the literature. These nanostructures can exhibit a type-I or a type-II band alignment, where the conduction-valence band mismatch between materials is such that electrons or holes are confined within the same layer of material for the former case and in different layers of the semiconductor for the latter case. Moreover, it has been shown that the change from type-I to type-II (or vice-versa) can be achieved by applying strain [5]. In this context, in this work, we theoretically investigate the electronic properties of charge carriers, within the effective mass approximation and the envelope wavefunction formalism, confined in heterostructured semiconductor nanowires composed of two semiconductor materials with different energy gaps grown along the wire-axis and with a circularly symmetric cylindrical shape (Fig. 1). Although initially the type-I confined potential of the semiconductor heterojunction acts as a well (barrier) region for electrons (holes), we demonstrate that modifications in the semiconductor compounds' concentration of nanowires and changes in the structural parameters of the system (nanowires radius and width of the central region of the heterojunction) make it possible to change the type of the band alignment which dictates the charge carrier confinement [6]. For some values of the wire radius and the effective masses ratios between the well and barrier regions, the contribution of the kinetic energy term for the total effective confinement potential becomes predominant with respect to the mismatched band potential, leading to switching the preferential spatial distribution of the wave functions to the barrier region for electrons, behaving like a type-II induced longitudinal junction, and a slope change is also observed in the energy spectrum of the investigated nanowire.

References

[1] Nature (London) **415**, 617 2002.
[2] Cryst. Growth Des. **11**, 3858 (2011); Nanotechnology **23**, 285601 (2012); Appl. Phys. Lett. **100**, 022110 (2012).
[3] Nature **420**, 57 (2002); Adv. Mater. **22**, 902 (2010).
[4] Semicond. Sci. Technol. **25**, 024005 (2010); Science **326**, 1247 (2009); Nature **415**, 617 (2002).
[5] Appl. Phys. Lett. **91**, 072108 (2007); J. Appl. Phys. **101**, 113703 (2007).
[6] J. Appl. Phys. **113**, 153710 (2013).

Figures

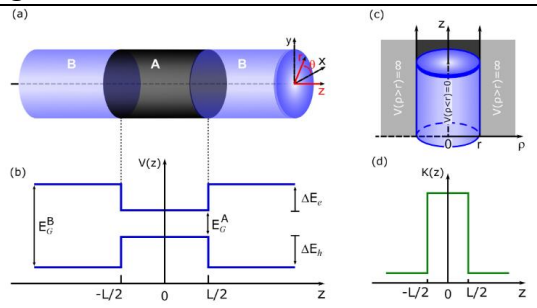

Figure 1: (a) Sketch of the heterostructured quantum wire building from block-by-block semiconductors materials. Schematic illustrations of the confinement potential along (b) the z-axis and (c) the radial direction, and (d) the kinetic energy contribution due to higher effective mass on the barrier region.