Electronic Band Structure of Bilayer Graphene Superlattices

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Abstract: We have studied the electronic band structure of bilayer graphene superlattices (BLGSLs) in two cases with different periodic potentials (arranged along the x-direction): (i) the δ-function electric potential with zero spatial average and (ii) the δ-function magnetic potential with zero average magnetic flux. In both cases, electronic band structures have been calculated within the four-band continuum model, using the transfer matrix mothod.

In the case of BLGSLs with electric potential the study shows that there exists the critial period $L = L_C$ so that for BLGSLs with $L < L_C$ a pair of zero-energy touching points (TPs) between the lowest conduction and the highest valence minibands is always generated in the $k_y = 0$-direction of the wave-vector $\vec{k}$, whereas for those with $L > L_C$ either such a pair of TPs exists or a direct band gap opens up, depending on the potential strength P. For these zero-energy TPs the dispersion relation derived shows the Dirac-like double-cone shape with the group velocity which is periodic in the potential strength P with the period of π and becomes anisotropic at large P. Study also shows the finite-energy TPs between higher minibands, from which those located at zero wave number are exactly identified. It seems that for these finite-energy TPs the dispersion is direction-dependent in the sense that it is linear or parabolic in the direction parallel or perpendicular to the superlattice direction, respectively. In addition, the "electron"- and "hole"-masses associated to the parabolic dispersion vary with P and L in very different ways.

In the other case of BLGSLs with magnetic potential the study shows that while the band dispersion related to the zero-energy TP is still isotropically parabolic like that for the pristine BLG, the periodic magnetic potential may induce a shift in the k_y-coordinate and a renormalization of the effective mass associated to this TP. Magnetic potential is shown also to generate the finite-energy TPs between higher minibands at the edges of Brillouin zone. The positions of these TPs and the related dispersions are exactly determined in the case of symmetric potentials.

In both cases, we have also calculated the density of states for the band structures examined and the low temperature conductivity which clearly demonstrate a manifestation of the TPs identified.

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