Graphene on Antidot Lattice: Electronic and Transport Properties.

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Abstract

Graphene bilayer systems are known to exhibit a band gap when the layer symmetry is broken, which can be achieved by applying a perpendicular electric field, thereby inducing opposite onsite potentials in the top and bottom layers.[1] The resulting band structure resembles that of a conventional semiconductor with a parabolic dispersion, where the band gap scales approximately linear with the applied field. Unfortunately, like other gapped graphene systems, the linear dispersion of single layer graphene is usually lost, as in the bilayer system. The implication of the parabolic dispersion is a lower mobility and thus degraded device performance.[2] To overcome this, we propose using heterogeneous multi- layered structures.

Bilayer superlattices have been studied in detail, with e.g. periodic potential barriers,[3] and dual-layer antidot-lattices.[4] A 1- or 2D potential modulation of the potential in bilayer graphene has even been predicted to yield linear dispersion.[5] However, heterostructure bilayers composed of two different single-layer systems has little theoretical support. Stacked heterostructures from multiple 2D materials created and held together only by van der Waals (vdW) forces[6] is particularly interesting as the interfaces may be kept clean from processing chemicals.

Here, we introduce a novel bilayer graphene heterostructure, where single-layer graphene is placed on top of another layer of graphene with a regular lattice of antidots, see Fig. 1. We dub this class of graphene systems GOAL: graphene on graphene antidot lattice. By varying the structure geometry, band structure engineering can be performed to obtain linearly dispersing bands (with a high concomitant mobility), Fig. 2, which nevertheless can be made gapped with the perpendicular field, Fig. 3. We have analyzed the electronic structure and transport properties of various types of GOALs, and found interesting behavior which should be possible to achieve in various similar bilayer heterostructures.

References

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Figures

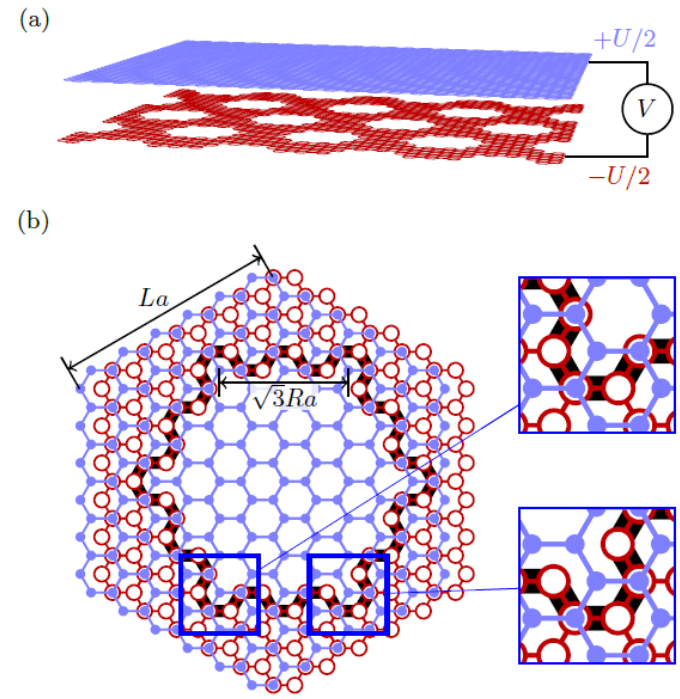

Figure 1

(a) Schematic illustration of the considered structures, consisting of a single graphene layer (blue) on top of a GAL layer (red), arranged in an AB stacking. (b) A closer view of the atomic structure of the Wigner-Seitz cell of a {*L*,*R*} = {6, 2} GOAL, with carbon atoms in the graphene (GAL) layer illustrated with blue filled circles (red open circles).

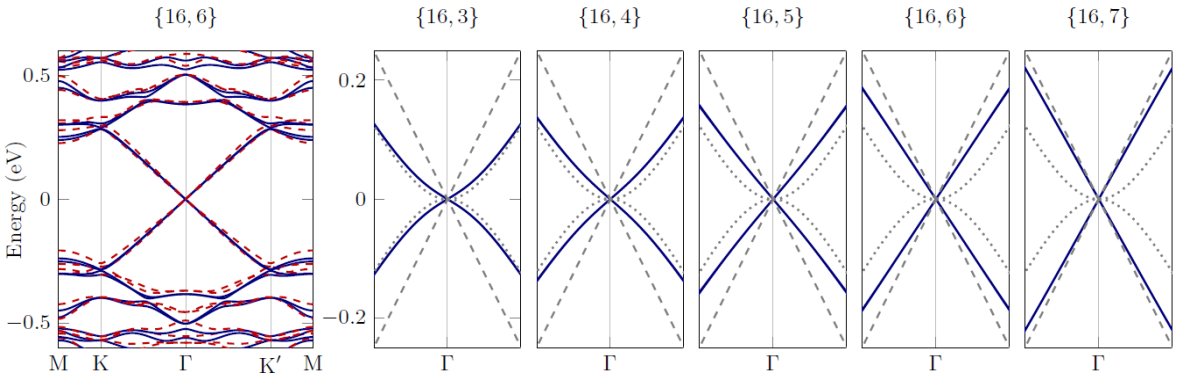

Figure 2

Band structures of f16;Rg GOALs. The left-most panel shows the full band structure within our model (solid blue lines), and for comparison the results obtained if skew scattering terms are included (red dashed lines). The right panels show a section of the band structure of GOALs near the point, for increasing antidot sizes, in solid lines. Dashed gray lines show the corresponding single-layer graphene dispersion, while dotted gray lines illustrate the bilayer graphene dispersion.

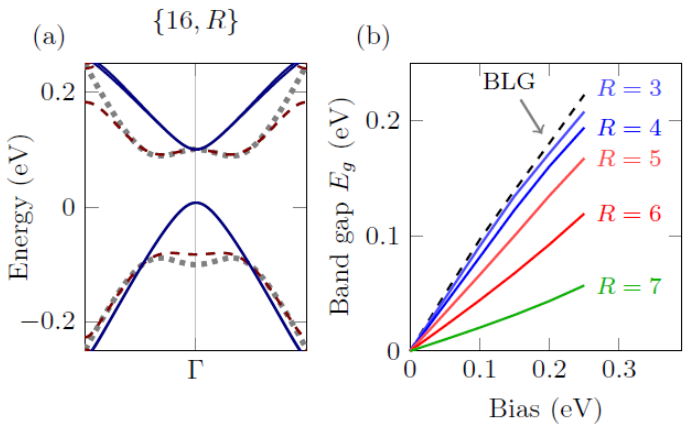

Figure 3

Band structures and gaps of biased various GOALs.(a) Band structures for the {16, 3} (red, dashed) and {16, 6} GOALs (blue, solid) and pristine bilayer graphene (gray, dotted), with a bias U = 0:2 eV applied across the layers. Note the bands resembling biased bilayer graphene, i.e. the "Mexican hat" profile, for the small antidot {16, 3} and those resembling gapped single-layer graphene for the large antidote {16, 6} GOAL. (b) Band gaps for {16, *R*} GOALs with *R* = 3, 4, 5, 6, 7 and an increasing bias. Note the mostly linear dependence on the bias for all antidot sizes.