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Title:A stable "flat" form of two-dimensional crystals: Could graphene, silicene, germanene be minigap semiconductors?
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Abstract:The discovery of a flat two-dimensional crystal known as graphene has contradicted Landau-Peierls-Mermin-Wagner arguments that there is no stable flat form of such crystals. Here, we show that the "flat" shape of graphene arises due to a microscopic buckling at the smallest possible interatomic scale. We show that the graphene, silicene, and other two-dimensional crystals are stable due to transverse short-range displacements of appropriate atoms. The distortions are small and form various patterns, which we describe in a framework of Ising model with competing interactions. We show that when temperature decreases, two transitions, disorder into order and order into disorder, arise. The ordered state has a form of stripes where carbon atoms are shifted regularly with respect to the plane. The flat graphene, silicene, or germanene planes look like a microscopic "washboard" with the wavelength of about couple of interatomic spacing of appropriate sublattices, which for graphene is about 1.8-3.6 A˚. At lower temperatures, the ordered state transforms into a glass. Because of up-down asymmetry in buckled graphene, silicene and other two-dimensional crystals deposited on substrate, a minibandgap may arise. We derive a criterion for the minigap formation and show how it is related to the buckling and to the graphene-substrate interaction. Because of the bandgap, there may arise new phenomena and in particular a rectification of ac current induced by microwave or infrared radiation. We show that the amplitude of direct current arising at wave mixing of two harmonics of microwave electromagnetic radiation is huge. Moreover, we predict the existence of miniexcitons and a new type of fermionic minipolaritons whose behavior can be controlled by the microwave and terahertz radiation. © 2012 American Chemical Society.
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