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Title: Graphene systems under external perturbations

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In this talk, I will review my recent first principles calculations on changes of electronic structures of single- and bi-layer graphene under external mechanical perturbations. First, I will show that the single particle spectrum of graphene under external mechanical strains can be described by the generalized Wely Hamiltonians with additional pseudo vector and scalar potentials (1). Second, the bilayer graphene under external inhomogeneous strains or homogeneous shears will show very interesting manifestations of pseudo-scalar potential (2) or pseudo-vector potentials with SU(4) symmetry (3), respectively. I will discuss the several spectroscopic consequences of such external mechanical perturbations in graphene systems (1-4). (1) S. Choi, S. Jhi, Y.-W. Son, Phys. Rev. B 81, 081407(R) (2010) (2) S. Choi, S. Jhi, Y.-W. Son, Nano Lett. 10, 3486 (2010) (3) Y.-W. Son et al, Phys. Rev. B. in press (2011). (4) D. Yoon, Y.-W. Son, H. Cheong, Phys. Rev. Lett. 106, 155502 (2011)