Requirements for Zero-Gap States in Organic Conductors

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Recently, massless Dirac fermions in monolayer graphene have attracted a great deal of attention due to the anomalous quantum Hall effect with a phase shift corresponding to Berry's phase, extremely high mobility, and other intriguing properties. It has been recently found that an organic conductor $\alpha$-(BEDT-TTF)$_2$I$_3$ has a similar zero-gap state under pressure [1]. Here, requirements for zero-gap states are discussed from the viewpoint of the tight-binding energy band. From the analytical solutions of the energy bands as well as the numerical energy-band calculations, most systems with two molecules in a unit cell do not have a contact point between the upper most and the second bands, whereas most systems with four molecules have a contact point. These systems usually have semi-metallic Fermi surface, but in the presence of non-stripe charge order [2], these compounds afford the actual zero-gap state very easily. Presently, $\alpha$-(BEDT-TTF)$_2$I$_3$ seems to be the only compound that fulfills all these requirements, but other possibilities are discussed.