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Topological Edge States of 2D SSH Model: Analytical View

Topological edge states are known to be robust to weak perturbations such as edge roughness and impurities and provide robust electronic transport channel. In zigzag edges of graphene, edge states appear at the energy near the Dirac point [1] and provide perfectly conducting channel [2]. Full energy spectrum and wavefunctions of graphene nanoribbons can be obtained by solving the equations of motion of tight-binding model using wave-mechanics approaches [3]. Recently, it was also pointed out that the graphene edge state can be attributed to the quantized topological phase called Zak phase [4], which is also known as the Berry phase in one-dimensional (1D) system.

A minimum theoretical model to demonstrate properties of Zak phase is Su-Schrieffer-Heeger (SSH) model, which has been originally proposed for studying the electronic states of polyacetylene [5]. In this model, the topological phase transition is governed by tuning the ratio between inter- and intra-cellular hopping. If inter-cellular hopping becomes larger than the intra-cellular one, finite Zak phase appears accompanying with the charge polarization. By extending the idea of 1D SSH model to two-dimensional SSH model (2D SSH model) on a square lattice as shown in Fig. 1(a), we have shown that topological phase transition occurs by tuning the ratio between inter- and intra-cellular hopping. This phase transition is characterized by the two-dimensional vectored Zak phase. As shown in Fig. 1(b), the topological edge states clearly appear in the topological phase. However, the emergence of edge states in ribbon systems is confirmed only by numerical calculations so far [6].

In this work, we analytically derive the full energy spectrum and corresponding wavefunctions of 2D SSH model under ribbon boundary condition by solving the equations of motion of 2D SSH model using wave-mechanics approaches. The obtained analytic solutions shed light on the bulk-edge correspondence of 2D SSH model. Analytic properties of wavefunctions for 2D SSH model with ribbon boundary condition will be discussed. Our results will serve to design new 2D materials which possess non-zero Zak phase and edge states which are necessary for robust electronic transport.

References

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Figures

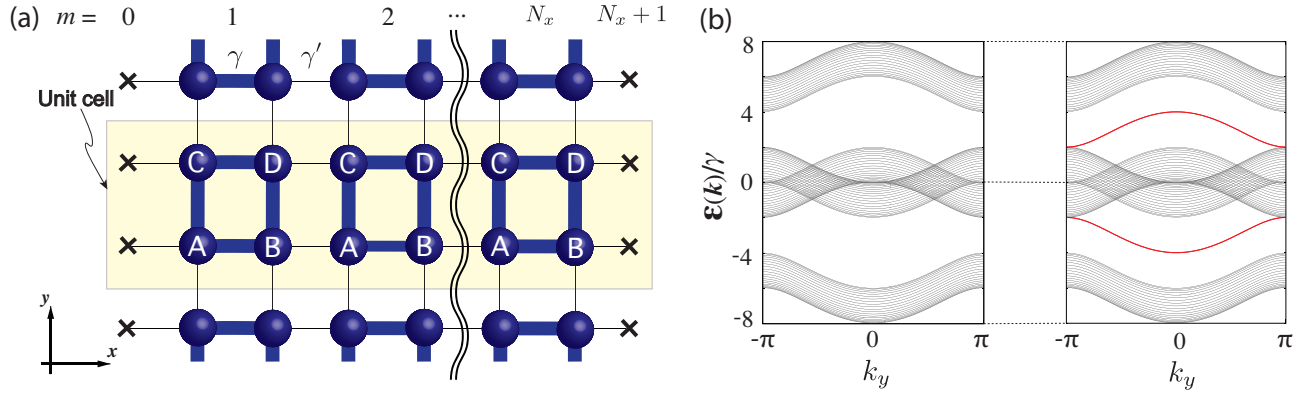


Figure 1: (a) Schematic ribbon structure of 2D SSH model. N_x is the ribbon widths. The \times marks indicate the missing atoms for boundary condition. (b) Energy band structure which Zak phase is zero (left) or nonzero (right) in case of $N_x=20$.