

Topological gapless phases in square lattice Kitaev model with additional hopping terms

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We investigate topological gapless phases in the square lattice Kitaev model with additional hopping terms. With nearest-neighbor hopping only, the model is known to exhibit gapless phases with two gapless points. When the magnitude of the newly added term is smaller than a certain value, the same phase diagram persists. We find that further increase of the extra hopping results in a new topological phase with four gapless points in addition to the known phases with two gapless points. We construct a phase diagram showing these gapless phases in the space of chemical potential and newly added hopping strength. Also, we examine how gapless points evolve as the chemical potential varies: they show up, separate into two points, move, merge, and disappear on the momentum plane. We also discuss the results in terms of the winding number of the topological defects in the auxiliary vector field.