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論 文 要 旨

THESIS SUMMARY

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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

The field of topological phases of matter is one of the playgrounds which have been intensively studied in condensed matter physics due to their intriguing topological properties. Topological crystalline insulators whose topological properties are ensured by crystal symmetry have been proposed recently as novel topological phases. The interplay between crystal symmetries, whose richness strictly constraints physical systems, and topology, which is conserved under continuous deformations, has played a crucial role in topological crystalline materials. Therefore, it is a promising topic to manifest such an interplay to broaden our knowledge of topological properties in crystalline materials, and to give a guideline to manipulate topological crystalline materials. In the present thesis, we theoretically explore the Z_2 magnetic topological crystalline insulators enriched by glide symmetry to investigate such an interplay and propose a manipulation.

Firstly, we study a general phase transition between the glide-Z_2 magnetic topological crystalline insulator and a normal insulator. In spinless systems, we find that the Weyl semimetal phase should emerge between topologically trivial and nontrivial phases. From our general argument describing such a phase transition based on an effective model, all the bands in spinless systems are free from degeneracy in general, and a gap closing between a single conduction band and a single valence band generally means a pair creation of Weyl nodes; hence the Weyl semimetal phase naturally appears. Because of the topological nature of the Weyl nodes, the trajectories of Weyl nodes are related to a change of the glide-Z_2 topological invariant. We support this conclusion by a calculation on a tight-binding model. The results of the model calculations totally agree with our general arguments of topological phase transition in spinless glide-symmetric magnetic systems.

Secondly, we manifest the interplay between the glide-Z_2 magnetic topological crystalline insulator and symmetry, by adding inversion symmetry while time-reversal symmetry is not enforced. There are two ways to add inversion symmetry, leading to the space group No. 13 or No. 14 from the space group No. 7 having glide symmetry only. In the space group No. 13, we find that the glide-Z_2 topological invariant is solely expressed in terms of the irreducible representations at high-symmetry points in momentum space. It constitutes the $Z_2 \times Z_2$ symmetry-based indicators for this space group, together with another Z_2 representing the Chern number modulo 2. In the space group No. 14, we find that the symmetry-based indicator Z_2 is given by a combination of the glide-Z_2 topological invariant and the Chern number. Thus, in the space group No. 14, from the irreducible representations at high-symmetry points we can only know possible combinations of the glide-Z_2 topological invariant and the Chern number, but in order to know each value of these topological numbers, we should calculate integrals of the Berry curvature. Moreover, we show that in both cases, the symmetry-based indicator Z_4 for inversion-symmetric systems leading to the higher-order topological insulators is directly related to the glide-Z_2 invariant and the Chern number. We also investigate topological invariants for glide-symmetric systems with a nonprimitive lattice with and without inversion symmetry, i.e., in the space groups No. 9 and No. 15. We derive new formulas of the glide-Z_2 topological invariant for the space groups No. 9 and No. 15, and we show that the glide-Z_2 topological invariant in the space group No. 15 behaves in the same way as that in the space group No. 13.

Thirdly, we consider a layer construction in magnetic systems as an independent approach to these results. For these space groups, we construct all invariants based solely on real-space geometric properties of the layers for each space-group operation in a given space group. In this process, we find that it is convenient to redefine the glide-Z_2 topological invariant proposed in the previous works to have agreement between real-space topology and k-space topology. By redefinition of the glide-Z_2 topological invariant, we show complete agreement between the results of the layer constructions and the above results for the topological invariants constructed from k-space topology. We also construct tight-binding models for the

glide-Z_2 magnetic topological crystalline insulator and the Chern insulator based on the layer constructions. The numerical calculations by using these models assist in our conclusions.

Finally, we investigate how this topological phase can be manipulated based on the relationship between space group representations and band structures, and discuss its consequences in photonic crystals. We clarify the condition that makes the photonic crystal in the space group No. 230 topologically nontrivial by using our theory and then argue which Wyckoff position in the space group No. 230 to put dielectrics in order to realize the glide-Z_2 magnetic topological crystalline insulator phase. By giving several configurations constructed from dielectrics located at various Wyckoff positions, we show the generated band structures correspond to our scenario. We expect that this study opens up new directions to study their interplay in bosonic systems including photonic systems.