

論文 / 著書情報
Article / Book Information

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Title(English)	Bulk-boundary correspondence of first- and second-order topological insulators and their effects on the crystal shapes
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Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

論文要旨

THESIS SUMMARY

系・コース： 物理学 系
Department of Graduate major in 物理学 コース
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申請学位(専攻分野)： 博士 (理学)
Academic Degree Requested Doctor of
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要旨 (英文 800 語程度)

Thesis Summary (approx.800 English Words)

The interplay between symmetry and topology leads to a wide range of topological phases of matter, such as topological insulators, topological crystalline insulators (TCIs) and second-order topological insulators (SOTIs). The topological phases are characterized by topological invariants in the bulk. When the topological invariant is nontrivial in a given insulator, the insulator has topological gapless states at the boundaries. The correspondence between the topology in the bulk and the boundary states is called bulk-boundary correspondence. The TCI has gapless surface states protected by crystal symmetries, and the SOTI has gapless states at the intersections between the surfaces, which are called hinge states.

Given that the topological materials possess gapless states at their boundaries, we need to consider a system with boundaries in order to study the topological boundary states. On the other hand, the topological invariant of the topological material is defined by the wave functions in the bulk without boundaries. Thus, in order to comprehend the relationship between the topology in the bulk and the topological boundary states, it is helpful to study the process of changing boundary conditions from periodic boundary conditions to open boundary conditions. We refer to this process as the “cutting procedure”. The purpose of this thesis is to discover and understand novel phenomena brought about by the topological phases via the cutting procedure. This procedure gives us two crucial pieces of information on topological phases of matter: (i) spectral flow and (ii) surface energy. The spectral flow is a flow of energy bands through the cutting procedure. Through an analysis of the spectral flows, we can show the bulk-boundary correspondence of the TCI and the SOTI, as we will discuss in the first half of this thesis. In addition, we can also obtain the surface energy via the cutting procedure. We apply the cutting procedure in one direction and get how much the energy changes through the cutting procedure, which gives us the surface energy. By studying the surface energies, we discover that the topological boundary states affect the surface energy, resulting in unique equilibrium crystal shapes.

In the first half of this thesis, we show the bulk-boundary correspondence of the TCIs and the SOTIs via the cutting procedures. We study behaviors of gapless states through the cutting procedure in one direction, and thereby we show that the surface states appear in terms of parity eigenvalues satisfying certain conditions. In addition, by applying the cutting procedures in two directions, we give a proof that the hinge states appear only from the parity eigenvalues. We also find all the possible configurations of chiral hinge states in SOTIs with inversion symmetry through an analysis of the sign of the surface Dirac mass. In particular, in the presence of glide symmetry, for particular surface

orientations, the surface Dirac mass changes sign by changing the surface terminations. By applying this result to a layered antiferromagnet, we find a difference in the hinge states between the cases with an even and odd number of layers. Furthermore, we show the bulk-boundary correspondence of the SOTI protected by rotoinversion symmetry. Then, based on the bulk-boundary correspondence, we propose a class of Weyl semimetal having the chiral hinge states protected by rotoinversion symmetry.

In the latter half of this thesis, we study surface energies of TCIs via the cutting procedure. We can obtain the surface energies in terms of the changes of the energy through the cutting procedure. It is now well-studied how chemical bondings determine crystal shape via the dependence of surface energies on surface orientations. We show that topological surface states affect surface energies and crystal facets in an unconventional way. By adding a magnetic field to a topological insulator, we can realize a TCI phase protected by mirror symmetry. In this TCI, the gapless states appear only on the surfaces which are invariant under the mirror operation. By studying changes in the crystal shapes through this process, we unveil that the anisotropy of the surface states affects the surface energy and the crystal shape. We also discuss the crystal shape of the SOTI and the effects of hinge states on the crystal shapes. In addition, we study the surface energies and the crystal shape of TCIs protected by glide symmetry. We show that the surface energy of glide-symmetric TCIs depends on the surface orientation in a singular way via the parity of the Miller index. This singular surface energy of the TCI affects equilibrium crystal shapes, resulting in the emergence of unique crystal facets of the TCI.

備考：論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。

Note: Thesis Summary should be submitted in either a copy of 2000 Japanese Characters and 300 Words (English) or 1 copy of 800 Words (English).

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