11–2 Properties of New Materials with Topology

— Classification of the Properties in Superconductors by Topology —

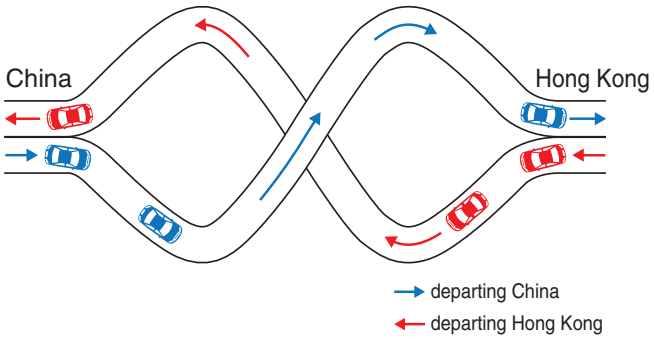

Fig.11-4 Non-trivial topological bridge
Mainland China and Hong Kong drive on opposite sides of the road. The above bridge can naturally connect the two. This bridge has a non-trivial topology.

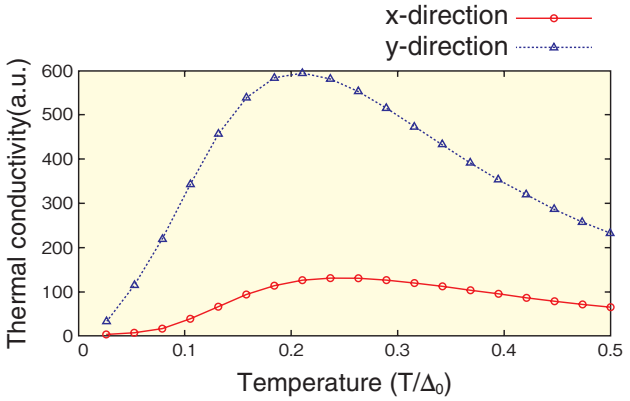

Fig.11-5 Angular dependence of the thermal conductivity
A certain type of topological superconductor has strongly anisotropic thermal conductivity due to the non-trivial topology.

Solids are characterized by the Metal, Semi-metal, Insulator in the conductive-order. Recently, the 4th solids where the bulk is insulating but the surface is metal called Topological insulator have been found. These novel materials can be classified by the mathematics called the Topology so that many scientists are attracted. In addition, this group of the materials has the high thermoelectric power.

Topology is the mathematical study of properties that are preserved under continuous deformations. For example, the bride shown in Fig.11-4 has the non-trivial topology. The topology distinguishes the topological insulators from the conventional solids.

Recently, the researchers have been found the fact that the topological insulator Bi_2Se_3 becomes the superconductor whose transition temperature is 3 K. This kind of the superconductors might be novel functional materials, since superconductivity can transfer the electricity without the energy lost so that it is promising material as the stand-alone device workable in the extreme environment where a human can not enter. However, the physical properties of this superconductor called the topological superconductor have been unknown. Therefore, we investigate the difference between Bi_2Se_3 and the conventional superconductors. Then, by focusing on the fact that the electrons are running ultra fact in Bi_2Se_3, in terms of the theory of the relativity, we can successfully classify the superconductors by the topology. The theory of the relativity hunted the non-trivial topology in the topological superconductors.

In terms of the description about ultra-fast particles in the theory of the relativity, we construct the theory of the thermal conductivity in this material. Then, we find that a certain type of the topological superconductor has the strong anisotropy of the thermal conductivity due to the non-trivial topology as shown in Fig.11-5. This phenomenon is originated from the fact that the twist in the space-time due to the non-trivial topology makes a certain crystal axis special.

We show that the mathematical study of the topology is important even in the superconductors. Novel functional materials and devices can be constructed in terms of the new topological materials in the future.

Reference

Nagai, Y. et al., Rotational Isotropy Breaking as Proof for Spin–Polarized Cooper Pairs in the Topological Superconductor $Cu_xBi_2Se_3$, Physical Review B, vol.86, issue 9, 2012, p.094507–1–094507-5.