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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 ）

In the anisotropic BCS states, such as non s-wave superconductors and superfluids, it is known that the property of the local states could significantly change from that of the bulk state by quasi-particle scattering by impurities, and boundaries. This is because quasi-particle feels change of the pair potential when it changes the direction by scattering, and scattering brings the greatest pair breaking effect when the sign of the pair potential changes. In the vicinity of a scattering object on the order of coherence length, superfluid order parameter is suppressed and quasi-particle bound states are formed within energy gap. When they are formed near surfaces or boundaries, they are called Surface Andreev Bound States (SABS).

Superfluid 3He is the first discovered p-wave spin triplet superfluid and the existence of SABS has been suggested theoretically. There are many materials thought to be the p-wave superconductors but none of their symmetry is completely determined. One the other hand, the bulk state of superfluid 3He has been established as a p-wave spin-triplet state and the symmetry of the some stable phases have been understood well. Further, high accurate experiments were possible since it is not affected by lattice defects and impurities. It is a very pure system. It can be said that in 3He is a very ideal material for studying the surface states. However, in contrast to the superconductors in which tunneling conductance measurements through boundaries are possible, there has been no effective probe for the surface states of the superfluid. Theoretical studies have progressed much, but experimental studies of the surface state has not been done until recently.

In recent years, it was pointed out quasi-particle in the SABS of superfluid 3He B phase is regarded as the Majorana fermions. The Majorana fermions, proposed by Ettore Majorana in 1937, are neutral particle where anti-particles are equivalent to particles. In the superfluid 3He on a specular surface, a linear dispersion relation is observed, that is one of the characteristics of the Majorana fermions; this linear dispersion relation is called Majorana cone. The Majorana fermion has not been identified yet in elementary particle physics, and thus the experimental

confirmation of the Majorana cone on the surface of the superfluid 3He is very important.

Recently, a new class of materials called topological insulators has been discovered and attracted much attentions. Topological insulator has an energy gap in the bulk, but has metallic gapless state in the edge. The bulk state of topological insulator is characterized by non-zero topological invariant. Outside of the topological insulator, the topological invariant is zero and cannot be smoothly connected to bulk. This leads to closing of the gap at the edge and the gapless edge state is formed. This relationship is called the bulk-edge correspondence. The superfluid 3He was proposed to be a topological superfluid and the SABS can also be regarded as the gapless surface states formed by a similar topological reason.

As mentioned above, the linear dispersion of SABS towards specular condition has been demonstrated by the transverse acoustic impedance measurement. But the linear dispersion is not a strong evidence that the Majorana fermions are realized in SABS. A more clean-cut evidence is needed to confirm the Majorana fermions. Due to the equivalence of the particles and their anti-particles, the degree of freedom should be reduced by half. As a consequence, it is predicted that they have a peculiar magnetic response. When the magnetic field is applied in the direction along the wall boundary, SABS do not respond at all. But it responds when it is applied perpendicular to the wall. This peculiar property should be manifested in the transverse acoustic impedance.

In the present work, the magnetic field effect on the transverse acoustic impedance measurement was tried for the first time to search for a new information on the Majorana fermions which are supposed to be realized in SABS of 3He B phase. It is clearly observed the tiny anomaly in the imaginary part of the transverse acoustic impedance when the field from 130 mT to 190 mT is applied under the boundary condition of diffusive limit. The most important finding in the present study would be the drop in the imaginary part of the acoustic impedance which is consistent with the opening of the Zeeman gap around zero energy. The result is analyzed with the recent theory and the reasonable agreement is obtained. The time reversal symmetry of the system is broken by the magnetic field and then it results in the opening of the gap near zero energy. This picture is consistent with the Majorana property of SABS.