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（博士課程）
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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 precision measurements, standards play a pivotal role as references for physical quantities. It is required for standards to be stable, reliable, and easy to use. To this end, the universal realization of physical quantities based on physical constants has long been pursued. In this dissertation, the development of measurement systems for two physical quantities, thermodynamic temperature and electrical resistance is reported. These quantities are contrasted in that the former is classical whereas the latter is realized in a macroscopic quantum phenomenon.

Firstly, the development of an acoustic gas thermometry (AGT) system and the measurement of the Boltzmann constant k is reported. AGT measures thermodynamic temperature using the relation between the speed of sound of a gas and temperature. The speed of sound of the ideal gas w can be written as $w^2 = \gamma kT/m$, where γ is the ratio of the heat capacity at constant pressure to that at constant volume and m is the mass of a molecular of the gas. If the numerical value of the Boltzmann constant and the molecular mass are both known, thermodynamic temperature is derived from the speed of sound. In this work, instead of measuring thermodynamic temperature based on the Boltzmann constant, the numerical value of the Boltzmann constant is determined; this measurement uses the relation $k = mw^2/\gamma T$, which is derived from the above equation. To measure the speed of sound precisely, acoustic resonance frequencies in a copper cavity is measured. To characterize the shape of the cavity *in-situ*, microwave resonance frequencies in the cavity are monitored. In order to facilitate the microwave measurement, the shape of the cavity is designed to be slightly deviated from a perfect sphere. By making the cavity triaxial-ellipsoidal, the three-fold degeneracy of the transverse electric (TE) and the transverse magnetic (TM) modes are resolved. In this work, argon is used as the measurement gas because thermophysical properties of a noble gas is well-known. In argon gas, the speed of sound w is dependent on pressure, expressed as $w(p)^2 = A_0+A_1p+A_2p^2+\ldots$, where $A_0= \gamma kT/m$. A_0 is derivable from extrapolating $w(p)^2$ measured different pressures to the limit $p\rightarrow 0$. In this research, the pressure was varied between 60 kPa and 420 kPa. As a result, the Boltzmann constant was measured with the uncertainty of 25 ppm.

Secondly, development of techniques for measurement of topological insulator are reported. The topological insulator is expected to be applied to a novel resistance standard based on the von Klitzing constant R_K. Today, the primary standard of electrical resistance is based on the quantum Hall effect (QHE). The QHE is a quantum phenomenon observed in a two-dimensional electron gas system in a low temperature and a high magnetic field. In the QHE, the diagonal elements of the conductance tensor disappear and off-diagonals become v/R_K, where v is an integer. The von Klitzing constant is expressed

only by fundamental constants, $R_K=h/e^2$. A disadvantage of the QHE is that it requires a large magnetic field. However, it is recently reported that in magnetically-doped topological insulators, the quantization of Hall resistance is realized without external magnetic fields. In this view, measurement of electrical transport properties of a topological insulator is focused. In this study, a topological insulator $Sn_{0.02}Bi_{1.08}Sb_{0.9}Te_2S$ (Sn-BSTS) is used. Sn-BSTS has a large bulk gap (typically approximately 300 meV), and in a low temperature, thermally excited bulk carriers are suppressed and surface-dominant conduction is realized. Single crystals of Sn-BSTS are synthesized by the modified Bridgman method and thinned by the scotch-tape method. Thin flakes of Sn-BSTS are then put on a p-doped Si substrate with a 90 nm-thick SiO_2 layer at the top. Au/Ti electrodes are made by the common electron-beam lithography method. After Hall bar devices are fabricated, control of the surface carrier density is attempted. To control the both of the top/bottom surfaces, the dual-gate device structure is employed. To control the carrier density on the bottom surface, the p-doped Si substrate was used as the back-gate electrode and the SiO_2 layer was used as the dielectric layer. As for the top surface, the carrier density is controlled by forming an electric double layer with an ionic liquid. As a result, the ambipolar transport on both surfaces are observed; the carrier control was successfully realized on the both surfaces as intended. Other than the Hall device, four-terminal Corbino devices are also fabricated and measured. By forming concentric electrodes, the path of electrical current is limited on the top surface and analysis becomes easier. Temperature dependence of four-terminal resistance measured on the Corbino device is measured. With the resistance-network model, which is newly proposed in this study, it is understood that surface-dominant conduction is successfully measured in the Corbino device, as intended.

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