§37. Thermopower and the Nernst Effect in the Quantum Hall System

Shirasaki, R. (Dep. Phys. Yokohama Nat. Univ.), Fujimoto, A. (Dep. Phys. Yokohama Nat. Univ.), Abe, T. (Dep. Phys. Yokohama Nat. Univ.), Hatano, N. (Ins. Industrial Sci., Univ. Tokyo), Hasegawa, Y. (Fac. Eng., Saitama Univ.), Komine, K. (Fac. Eng., Ibaragi Univ.), Endo, A. (Ins. Solid Stat., Phys., Univ. Tokyo), Fujii, T. (Ins. Solid Stat., Phys., Univ. Tokyo), Hu-Jun, Q. (Nagoya Univ.), Goryo, J. (Nagoya Univ.), Ohtani, H., Nakamura, H.

We calculate the Seebeck S_{xx} and the Nernst S_{yx} components of the thermopower tensor $\hat{S}$ in the quantum Hall system, using analytical formulas of the conductivity tensor $\hat{\sigma}$ that we deduced in a previous publication [1)].

The results basically reproduce the magnetic-field dependence of experimentally observed behavior of S_{xx} and S_{yx}. In Fig. 1, we plot, as a function of the magnetic field, the Seebeck component $S_{xx}(T,\varepsilon_{\rm F})$ and the Nernst component $S_{yx}(T,\varepsilon_{\rm F}) = -S_{xy}(T,\varepsilon_{\rm F})$ of the thermopower tensor calculated using analytical formulas of the conductivity tensor at $T = 0.1$ K. Here, we adopted the following sample parameters: the Fermi energy $\varepsilon_{\rm F} = 10.7$ meV, $p = 1.5$, the impurity scattering time $\tau_q = 3.8 \times 10^{-12}$ s, the momentum relaxation time $\tau_m = 3.8 \times 10^{-11}$ s, and the effective mass of the carrier $m^* = 0.067 m_0$ with m_0 the bare electron mass.

With the aid of the Mott relation valid at low temperatures, we can further simplify the expressions and obtain analytical formulas for S_{xx} and S_{yx}. The Mott relation predicts that both S_{xx} and S_{yx} grow linearly with the temperature T.

To examin the range of the validity of the formula based on the Mott relation, we investigate the temperature dependence of the height of $|S_{xx}|$ peak for various values of the impurity scattering time τ_q. In Fig. 2 we compare $S_{xx}(T,\varepsilon_F)$ obtained using our analytical expression and $S^M_{xx}(T,\varepsilon_F)$ given by the Mott relation when the Fermi energy lies at the first excited ($N = 1$) Landau level. As the scattering time becomes longer, the characteristic temperature at which S_{xx} deviates from the linear T dependence becomes lower.

We thus conclude that the Mott relation becomes inapplicable and the Seebeck component S_{xx} asymptotically approaches the universal value $(2\ln 2/3)(k_B/e)$ at the temperatures higher than $\hbar/(2\tau_q k_{\rm B})$, namely when $k_{\rm B}T$ becomes larger than the impurity broadening $\Gamma = \hbar/(2\tau_q k_{\rm B})$ of the Landau levels.

acknowledgements The work is supported by a Grant-in-Aid for Scientific Researchs (C) No. 22560004, (C) No. 22540425 and (B) No. 20340101.

1) A. Endo, N. Hatano, H. Nakamura, and R. Shirasaki, J. Phys.: Condens. Matter **21** (2009) 345803

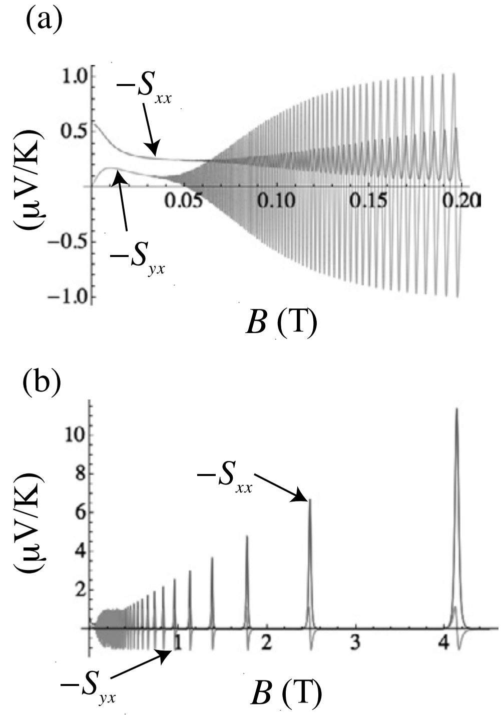

Fig. 1: Analytical result of Seebeck $S_{xx}(T,\varepsilon_{\rm F})$ and Nernst $S_{yx}(T,\varepsilon_{\rm F})$ components of the themopower tensor at $T = 0.1$ K in the magnetic field range (a) 0 T $< B <$ 0.2 T and (b) 0 T $< B <$ 4.5 T.

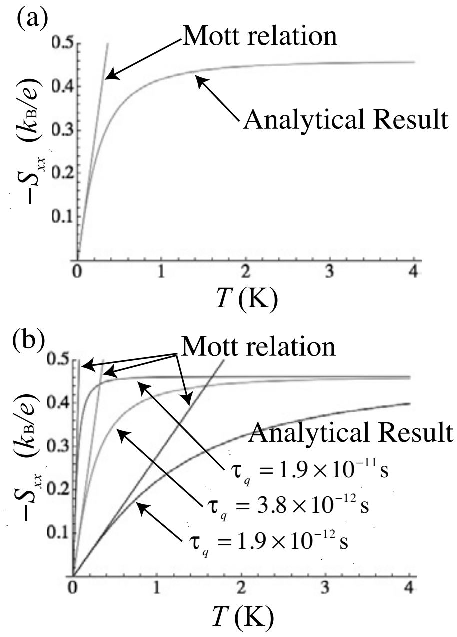

Fig. 2: Temperature dependence of $S_{xx}(T,\varepsilon_F)$ obtained using our analytical expression and $S^M_{xx}(T,\varepsilon_F)$ given by the Mott relation at the first excited ($N = 1$) Landau peak, in the unit of $k_{\rm B}/e$. (a) $\tau_q = 3.8 \times 10^{-12}$ s and $\tau_m = 10\ \tau_q$. (b) $\tau_q = 1.9 \times 10^{-12}$ s, 3.8×10^{-12} s, and 1.9×10^{-11} s with the fixed ratio $\tau_m/\tau_q = 10$.