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Theory of magnetoresistace: The origin of the modified Kohler's rule in high-Tc cuprates

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The transport phenomena under the magnetic field are very important and interesting field in condensed matter physics. Especially, the magnetoresistance (MR), $\Delta\rho/\rho$, is of current interest. In fact, the MR shows striking non-Fermi liquid behaviors in some strongly correlated electron systems. In high-T_c cuprates, for example, the Kohler's rule for the MR is violated in a wide range of temperatures. Moreover, it is noteworthy that an intimate relation between $\Delta\rho/\rho$ and the Hall coefficient (R_H), $\Delta\rho/\rho \propto (R_H/\rho)^2$, holds well experimentally, which is called the 'modified Kohler's rule'.

Because of the simplicity, the RTA is commonly used despite of lack of conserving laws. However, the RTA is dangerous as it may give unphysical results in correlated electron systems. In the present work, we derive the general expression for the MR due to the Lorentz force is derived by using the Fermi liquid transport theory based on the Kubo formula [1]. The obtained gauge-invariant expression is 'exact' of order $O(\tau^2)$. In the next stage, we study the anomalous behavior of the MR in high-T_c cuprates in terms of the nearly antiferromagnetic (AF) Fermi liquid [2]. We analyze the derived exact expression by including all the vertex corrections to keep the conserving laws, and find the approximate relation $\Delta\rho/\rho \propto \xi_{AF}^4 \cdot \rho^{-2}$ in the presence of the AF fluctuations (ξ_{AF} being the AF correlation length). The factor ξ_{AF}^4, which comes form the vertex corrections for the current, gives the additional temperature dependence. By taking account of the relation $R_H \propto \xi_{AF}^2$ which was derived in Ref.[3], we can naturally explain the modified Kohler's rule, which fails if we neglect some vertex corrections.

In conclusion, based on the Fermi liquid theory, the famous *seemingly* non-Fermi liquid behaviors of R_H and $\Delta\rho/\rho$ in high-T_c cuprates are naturally understood on the equal footing.

[1] H. Kontani, cond-mat/0011328

[2] H. Kontani, cond-mat/0011327

[3] H. Kontani, K. Kanki and K. Ueda: Phys. Rev. B 59 (1999) 14723.