学位論文の要約

題目　Spin Fluctuations of Itinerant Electron Magnetism in Iron-Gallium Intermetallic Systems
（鉄ガリウム系金属間化合物における遍歴電子磁性のスピンゆらぎ）

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序論

Electron-electron correlations in itinerant-electron systems draw great attention in the field of magnetism. Understanding the mechanism is crucially important in academic studies and technical applications. The author studied the magnetic and electrical properties of Ge and Co substitutions for $FeGa_3$, i.e. the electron doping dependence in $FeGa_{3-y}Ge_y$ and $Fe_{1-x}Co_xGa_3$ systems. The purpose of this thesis is to investigate the effects of electron concentration in $FeGa_3$. Spin fluctuations are found to play an important role in these systems. This thesis contains 5 parts： Chapter 1, a general introduction. Chapter 2, sample preparation and experimental procedure. Chapter 3, crystal structure and physical properties of parent compound $FeGa_3$. Chapter 4, weakly ferromagnetic $FeGa_{3-y}Ge_y$, and Chapter 5, nearly ferromagnetic $Fe_{1-x}Co_xGa_3$.

Chapter 3, Kondo-Insulator-like $FeGa_3$

In the chapter 3, the author introduced crystal structures, magnetic properties and electrical resistivity of $FeGa_3$. $FeGa_3$ crystallizes in a tetragonal structure with space group $P4_2/mnm$. The magnetic atom Fe makes pairs and forms spin singlet. There are two types of Ga sites exist in $FeGa_3$. Magnetization measurement shows $FeGa_3$ is diamagnetic. The temperature dependence of electrical resistivity has been investigated. An “S” shape temperature dependent resistivity was shown in the temperature range of 5 – 300 K. At low temperature, a relation $\rho(T) \propto \exp(\frac{T_M}{T})^{1/4}$ was estimated on a logarithmic scale. The relation indicates the variable range hopping (VRH) among the Anderson localized states in 3D systems. At temperature above 260 K, energy gap of $FeGa_3$ was estimated to be about 0.4 eV using the Arrhenius law.

Chapter 4, Modulated Ferromagnetic Metal $FeGa_{3-y}Ge_y$

A serial of $FeGa_{3-y}Ge_y$ compounds up to y = 0.32 were synthesized, and confirmed to be single crystals without second phase. By the measurement of nuclear quadrupole resonance (NQR), the temperature dependence of recovery curves $m(t)$ are obtained for y = 0.18 under 77 K. The exponent of spin-lattice relaxation indicates Ge prefer to take one site of Ga for substitution. To investigate the doping effects in $FeGa_{3-y}Ge_y$, magnetic and electrical measurements have been performed. The Ge substitution strongly affects magnetic properties and the electronic state in $FeGa_{3-y}Ge_y$. Phase transitions from a diamagnetic insulator into paramagnetic metal and then into a weakly itinerant ferromagnet were observed. At low level of substitution, Arrott plots are a serial of curves. And the curvature reduces with increasing y. For a relatively high y concertation, Arrott plots show a serial of straight lines. This phenomenon is explained by band calculation of magnetic free energy. And a higher expansion coefficient should be introduced to give a better description of magnetic isotherms. M^4 plots were introduced to estimate the magnetic critical temperature instead of using Arrott plots. Much clearly linear behavior of M^4 plots is observed, which can be explained in terms of Takahashi's theory of spin fluctuations. All of the spin-fluctuations parameters were estimated merely from macroscopic magnetic measurements without pursuing further dynamical investigations, such as nuclear magnetic resonance or neutron scattering etc. And magnetic properties of $FeGa_{3-y}Ge_y$ are quantitatively explained by taken into account the effects of mode-mode coupling of spin fluctuations.

Chapter 5, Nearly Ferromagnetic $Fe_{1-x}Co_xGa_3$

Electron doping by Co for Fe site in $FeGa_3$ were investigated in chapter 5. Single crystals for various composition from x = 0 to 1 were synthesized. $Fe_{1-x}Co_xGa_3$ turns a metal by Co substitution. Magnetic properties of $Fe_{1-x}Co_xGa_3$ were investigated by performing isothermal magnetization measurements. Both of ending compound, $FeGa_3$ and $CoGa_3$ are nonmagnetic. With the substitution of Co, the magnetization of $Fe_{1-x}Co_xGa_3$ increases first and achieve maximum at x = 0.2, and then decreases and the compound becomes the diamagnetic $CoGa_3$. To analyze the magnetic properties of $Fe_{1-x}Co_xGa_3$, spin-fluctuation parameters, such as fourth order expansion coefficients of magnetic free energy, the magnetic susceptibility in the frequency and wave-number space etc., were estimated from measuremetns such as, Arrott plots, temperature dependence of magnetic susceptibility at low temperature, based on self-consistent renormalization theory and Takahashi's theory of spin fluctuations. Relatively good agreements between experimental observations and theoretical estimations were obtained in the end.