Abstract

In heavy-fermion systems, two competing interactions originating from the interplay between localized electrons and conduction electrons play an important role; one is the Ruderman-Kittel-Kasuya-Yosida interaction and the other is the Kondo coupling. Their competition leads to a quantum critical point between a magnetically-ordered state and a Fermi liquid state, and quantum fluctuations enhanced near the quantum critical point are the source of interesting phenomena. As a new paradigm of the quantum critical phenomena, in this thesis, we explore the effect of geometrical frustration in the competing region. The aim of our study is to find a novel ordering emergent from a synergetic effect between the quantum criticality and geometrical frustration. In particular, we focus on the possibility to have a peculiar partial disorder, that is, coexistence of nonmagnetic Kondo singlet and magnetic order. Such partial disorder was observed in several rare-earth compounds with frustrated lattice structures, but the detailed nature of the partially disordered states was not clarified yet; especially, much less is known theoretically about the electronic structure and critical properties of phase transitions.

In this thesis, we investigate the ground-state phase diagram of the periodic Anderson model on a triangular lattice by employing the mean-field approximation. Beyond the previous theoretical studies, we investigate the problem more systematically in a wider parameter range. As a result, we find a collection of different types of the partially disordered states, both insulating and metallic, depending on the model parameters. At half-filling, we obtain a partially-disordered insulating state between a noncollinear antiferromagnetic metal and a Kondo insulator. The partially disordered state is stabilized by releasing the frustration with self-organizing the system into the coexistence of collinear antiferromagnetic order on unfrustrated honeycomb subnetwork and nonmagnetic state at the remaining sites. In addition, we study the effect of the spin anisotropy, external magnetic field, and carrier doping on the partially-disordered insulating state at half-filling. We find that the spin anisotropy introduced by the Ising coupling between localized electrons makes the partially disordered state more stable. In applied magnetic field, the system shows characteristic transitions between the partially disordered insulator, spin-canted insulator, Kondo insulator, and ferromagnetic metal. When we dope carriers to the partially disordered state, although there is a strong tendency toward phase separations, we find a partially-disordered metallic state in the electron doped region under a substantial Ising coupling. The nature and origin of the metallic partial disorder are discussed in detail. We extend the analysis to other commensurate fillings. In consequence, we find another type of partially-disordered insulating states at two commensurate fillings, 2/3 and 8/3 fillings. These states show different nature from that at half-filling: The nonmagnetic sites appear to be simply paramagnetic rather than

the singlet state due to the hybridization; they are not separated from but rather connected with the magnetic sites. Reflecting the difference, the partially disordered states at 2/3 and 8/3 fillings exhibit distinct responses to the spin anisotropy and magnetic field compared to the half-filling case. As a particularly interesting point, we find that the partially-disordered insulating state at 2/3 filling is changed into a partially-disordered metallic state by hole doping without showing a phase separation. This metallic state is stable without the help of spin anisotropy, and becomes unstable when the anisotropy is increased.

The present thesis provides a comprehensive analysis of the partial disorder phenomena in the ground state of the periodic Anderson model on a triangular lattice at the mean-field level. The results suggest that there is a variety of partially disordered states in heavy-fermion systems. In particular, we unveil that the model exhibits, at least, two different categories of the partially disordered states depending on the electron density. They show qualitatively different responses to the spin anisotropy, magnetic field, and carrier doping. The origin of the different behaviors is ascribed to the nature of the nonmagnetic sites in the partially disordered states. Our results will provide a firm ground for deeper understanding of the frustration-induced phenomena in the quantum critical region in heavy-fermion systems.