Abstract

Kondo semiconductors (KSs) or Kondo insulators are strongly correlated electron compounds where at low temperatures a narrow energy gap opens at the Fermi level within an enhanced electronic density of states (DOS). These systems behave like metals with localized magnetic moments at high temperatures, just as the heavy fermion metals, but like paramagnetic semiconductors at low temperatures. Some aspects of the anomalous low-temperature behaviour can be understood with simple band models based on the Kondo effect, but others evade this description. Therefore different effects have been evoked to describe anomalous features in KSs. The anisotropy in CeNiSn, for instance, was ascribed to a nodal Kondo gap. Recently it has been suggested that the residual conductivity observed in most KSs at the lowest temperatures might come from topologically protected surface states. This makes KSs promising candidates for topological insulators with strong correlations. Due to the strong energy dependence of the electronic DOS at the Fermi level, KSs generally have large thermopower. In contrast to specific heat, which is also enhanced, thermopower is a directional probe and can thus deliver important information on anisotropies.

In this work several single crystals of the tetragonal KS $CeRu_4Sn_6$ were grown and characterized by means of thermoelectric and thermal transport measurements, and other complementary measurement techniques (for instance electrical transport, specific heat, and inelastic neutron scattering). Due to the high level of sophistication involved in thermoelectric and thermal transport measurements, no commercial devices are available for measurements at low temperatures and high magnetic fields. Therefore setups for measurements of thermal conductivity, thermopower, and Nernst effect in the range of 0.05 to 300 K and in fields up to 12 T were set up within this work, and high-field facilities with dedicated thermal transport setups were used for fields up to 35 T.

All data were analyzed in terms of various models for Kondo systems and compared to results on other KSs. Striking results are, for instance, (i) the vastly different temperature dependence of the thermopower within the tetragonal (a-a) plane and perpendicular to it that indicates a much stronger Kondo interaction within the a-a plane, (ii) the high-field dependence of the thermopower at low temperatures that suggests a much faster suppression of the Kondo gap within the a-a plane, and (iii) indications for incoherent Kondo or non-Fermi liquid behavior from specific heat, thermal transport, and inelastic neutron scattering at the lowest temperatures. All these help to better understand effects of incomplete Kondo gap openings that are of interest also for the emerging field of topological Kondo insulators.