Abstract

Strongly correlated electron systems are among the most intriguing and versatile materials, and their theoretical description and understanding represent one of the greatest challenges in condensed matter physics. Ce-based compounds may be considered as a canonical example of strongly correlated electron systems, in which heavy fermion behaviour, Kondo effect, fluctuating valence, non-Fermi liquid behaviour, superconductivity, magnetic ordering, and many others can occur. These effects can be stimulated by external or internal (alloying) pressure or by application of magnetic field. The effects of the dilution depend on the position of the parent Ce-based compound on the Doniach Diagram, which is determined by a competition between Ruderman-Kittel-Kasuya-Yosida interaction and screening of the magnetic moments originating from the Kondo effect.

The PhD Thesis is aimed at a modification of the hybridization strength between the 4f electrons and conducting electrons, via chemical substitutions to pass continuously between heavy fermion system, spin glass behaviour, ferromagnetic order and fluctuating valence regime. To study the problem we have chosen four series of isostructural compounds: $Ce(Cu_{1-x}Ni_x)_4Mn$, $Ce(Cu_{1-x}Ni_x)_4Al$, $CeCu_4Mn_yAl_{1-y}$, and $CeNi_4Mn_yAl_{1-y}$.

Physical properties (magnetization, electrical resistivity and specific heat in the temperature range from 2 to 300 K) have been determined for polycrystalline samples obtained by induction melting in argon atmosphere. Rietveld refinement of the X-ray powder diffraction data has confirmed that all the new alloys crystallize in the hexagonal $CaCu_5$-type structure (P6/mmm space group). Chemical substitutions lead to a structural disorder, i.e. Cu, Ni, Mn, and Al are statistically distributed over the 2c and 3g lattice sites. The results of DC and AC magnetic susceptibility have indicated formation of the spin glass state for all Mn containing alloys except $CeNi_4Mn$. The spin glass behaviour has been confirmed by a lack of the specific heat and electrical resistivity anomaly. Magnetic phase diagrams were determined for the $Ce(Cu_{1-x}Ni_x)_4Mn_yAl_{1-y}$ compounds.

$Ce(Cu_{1-x}Ni_x)_4Mn$ is a substitutional magnetic system where an interplay of different magnetic interactions leads to the disappearance of the long-range magnetic order inherent to $CeNi_4Mn$. The existence of the spin glass and ferromagnetic behaviour for $0.25 \leq x \leq 0.625$ has been revealed.

Results obtained for $Ce(Cu_{1-x}Ni_x)_4Al$ point to a transition from the Kondo lattice to the fluctuating valence state without the dilution of Ce but by the progressive change of the 3d element. The transition is accompanied by a decrease of the electronic specific heat coefficient, increase of the splitting of the crystal field levels and damping of the resistivity maximum.

A possible coexistence of the spin glass and the heavy fermion state for $CeCu_4Mn_yAl_{1-y}$ compounds with $0 < y \leq 0.3$ has been observed. The spin glass freezing temperature has been found to increase linearly with the Mn concentration.

Various measurements on $CeNi_4Mn_yAl_{1-y}$ system have indicated that Mn/Al substitution results in the spin glass behaviour. No clear sign of valence fluctuation has been observed for samples containing Mn.

Physic of the investigated compounds is governed by a mutual balance of the Kondo effect, Ruderman-Kittel-Kasuya-Yosida interaction, structural disorder, and crystalline electric field effects, resulting in most cases in the spin glass behaviour.