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Neutron scattering study of the Kondo insulators CeT_2Al_{10} (T=Fe,Ru,Os)

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The recent discovery of topological Kondo insulating behaviour in strongly correlated electron systems has generated considerable interest in the field of Kondo insulators both experimentally and theoretically. The Kondo semiconductors CeT2Al10 (T=Fe, Ru and Os), crystalizing in the orthorhombic crystal structure, possessing a c-f hybridization gap have received considerable attention recently because of the unexpected high magnetic ordering temperature of CeRu2Al10 (TN=27 K) and CeOs2Al10 (TN=28.5 K) and the Kondo insulating behaviour observed in the valence fluctuating compound CeFe2Al10 with a paramagnetic ground state down to 50 mK [1-3]. We are investigating this family of compounds using neutron diffraction, inelastic neutron scattering (INS) and muon spin rotation/relaxation (μSR) measurements to understand the role of anisotropic c-f hybridization on the anomalous magnetic structure, anisotropic magnetic exchanges, and spin gap formation as well as on their magnetic and transport properties. Our neutron diffraction studies on T=Ru and Os show that the magnetic ordering with propagation vector K=[1 0 0], but the direction of the moment is along the c-axis, which is not the easy axis of the magnetization. Further the ordered state moment is much smaller than that expected from the J=5/2 state of Ce3+ ion. We will show that the observed magnetic structure, direction and magnitude of the moment, is very sensitive to the electron and hole-doping in these compounds, but the crystal structure remains the orthorhombic. . We have observed a clear sign of a spin gap in all three compounds from INS study as well as the existence of a spin gap above the magnetic ordering temperature in T=Ru and Os. Our INS studies on single crystals of CeRu2Al10 and CeOs2Al10 revealed dispersive gapped spin wave excitations below TN [3]. Analysis of the spin wave spectrum reveals the presence of strong anisotropic exchange, along the c-axis (or z-axis) stronger than in the ab-plane. These anisotropic exchange interactions force the magnetic moment to align along the c-axis, competing with the single ion crystal field anisotropy (CEF), which prefers the moments along the a-axis. In the paramagnetic state (below 50 K) of the Kondo insulator CeFe2Al10, we have also observed dispersive gapped magnetic excitations which transform into quasi-elastic scattering on heating to 100 K [3]. We will discuss the origin of the anisotropic hybridization gap in CeFe2Al10 based on theoretical models of heavy-fermion semiconductors. Further the effect of electron- and hole-doping as well as chemical pressure effect on the magnetic and transport properties of CeT2All0 compounds will be discussed based on our INS and μSR results. Our μSR study reveals a long range magnetic ordering for electron doping in the Kondo insulator CeFe2Al10. We will compare the results of our INS study of CeT2Al10 with that of topological Kondo insulators, such as SmB6, CeNiSn and CeRu4Sn6.

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