High Magnetic Field de Haas-van Alphen Measurements of RT_2Zn_{20} (R=Yb and Lu, T=Fe, Co and Rh)

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Introduction

Intermetallic compounds, RT_2Zn_{20} (R = rare earth, T = transition metal in Fe and Co groups), containing less than 5 at. % rare earth ions, can serve as model systems for the study of local and hybridizing moment magnetism in a regime that approaches the single ion limit while preserving periodicity.[1-3] Previous studies indicated that this system range from a nearly ferromagnetic Fermi liquid (NFFL) (YFe_2Zn_{20} and $LuFe_2Zn_{20}$),[1,3] to greatly enhanced ferromagnetic $GdFe_2Zn_{20}$,[1,3] all the way to heavy fermion ground state in YbT_2Zn_{20} (T = Fe, Ru, Os, Co, Rh, and Ir).[2]

Among all these physics, YbT_2Zn_{20} family maybe the most conspicuous: these 6 compounds manifest heavy fermion ground states associated with varied Kondo temperature (T_K) and Fermi liquid behaviors, albeit the crystal electronic field (CEF) effect is thought to be essentially similar.[2] For example, $YbFe_2Zn_{20}$ has $T_K \sim 30K$ and electronic specific heat $\gamma_0 \sim 500$ mJ/molK^2, whereas $YbCo_2Zn_{20}$ appears $T_K \sim 1K$ and $\gamma_0 \sim 8000$ mJ/molK^2. Given that their Lu isostructural analogues manifest varying degrees of correlation, a study of the electronic structure of Yb and Lu analogues will help to reveal the correlation between the Kondo state of Yb ions and the electronic background.

Experimental

The de Haas–van Alphen (dHvA) effects were measured on the single crystals of YbT_2Zn_{20} (T = Fe, Co and Rh) as well as their Lu analogues (the samples were grown in Ames Lab), with applied magnetic field along their [110] crystallographic direction in the temperature range from 0.4K to 12K, by using the in 60 tesla long pulse magnet facility in NHMFL, Los Alamos. In addition to the dHvA measurements, high field magnetization measurements were also preformed on $LuFe_2Zn_{20}$, to detect the possible existent iterant metamagnetic transition (IMMT) in this NFFL system.

Results and Discussion

At least one dHvA oscillation frequency was detected for each of these six compounds. For the Lu compounds, the NFFL one, $LuFe_2Zn_{20}$, manifests obviously different frequencies compare with the rest, whereas the Co and Rh compounds present similar frequencies. Self-consistent tight binding linear muffin-tin orbital method in the atomic sphere approximation (TB-LMTO-ASA) was used to construct Fermi surfaces of LuT_2Zn_{20} (T=Fe, Co and Rh). The calculated dHvA frequencies show good agreement with the experiments. The three Yb analogues, presenting different frequency, manifest cyclotron effective masses range from $1.8m_0$ to $2.8m_0$, according to the dHvA measurements at varied temperatures.

The IMMT did not appear up to 60T at 0.4K for $LuFe_2Zn_{20}$.

Conclusions

The electronic structure of YbT_2Zn_{20} and LuT_2Zn_{20} demonstrate variation for different transition metal according to the dHvA measurements. Further dHvA measurements along different crystallographic orientations ([100] and [111]), as well as the band structure calculation on Yb compounds, will help to understand the divided heavy Fermi ground state of YbT_2Zn_{20}.

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References

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