Experimental report

16/09/2015

Proposal: **TEST-2514** **Council:** 10/2014

Title: First investigation of UCo0.995Ru0.005Al

Research area:

This proposal is a new proposal

Main proposer: **Milan KLICPERA**

Experimental team: Milan KLICPERA

Local contacts: Paul STEFFENS

Samples: UCo0.995Ru0.005Al

Instrument	Requested days	Allocated days	From	To
THALES	2	2	04/08/2015	06/08/2015

Abstract:

Experimental report

Experimental title: **First investigation of $UCo_{0.99}Ru_{0.01}Al$**

Proposal number: **TEST-2514**

Instrument: **ThALES**

Date of experiment: 1. – 3.7. 2015

Local contact: Paul Steffens

Experimental team: Milan Klicpera[1,2]

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Abstract: UCoAl crystallizes in hexagonal ZrNiAl-type structure. The shortest distance between two uranium atoms in compounds with ZrNiAl-type structure is always found in the basal plane. Consequently the 5f wave functions of uranium mostly interact in basal plane and the 5f orbitals are then compressed towards the basal plane. This fact together with the orbital polarization of 5f states (due to the strong spin-orbit coupling) lead to magnetic moments oriented parallel to the c-axis, which becomes the easy magnetization axis.

UCoAl is paramagnet very sensitive to the influence of external magnetic field and/or pressure. The small magnetic field leads to the metamagnetic transition to the ferromagnetic state. For its phase diagram, UCoAl is thus often called quantum itinerant ferromagnet. Another driving parameter is the substitution of one of the constituent elements. One of the most interesting substitutions is Co-Ru doping, which represents subject of our broader research.

Scientific background:

UCoAl is paramagnet down to lowest temperatures. By applying external magnetic field of ~ 0.7 T along the c-axis at low temperatures, we observe metamagnetic transition of the first order into itinerant ferromagnetic state [1, 2]. Huge magnetocrystalline anisotropy is preserved even in paramagnetic state. Broad maximum in magnetic susceptibility around 20 K and no considerable anomaly in electrical resistivity and heat capacity data around this temperature represent another interesting phenomenon and is presumably associated to metamagnetic transition similarly as in $LuCo_2$ and YCo_2 [3]. Metamagnetic transition changes from crossover regime to first-order transition at critical endpoint (CEP) at 11 K [2]. CEP temperature is suppressed and critical field increases under applying hydrostatic pressure. Magnetic phase diagram was drafted up by Aoki et al. and could be found in Ref. [4]. Compounds with similar phase diagram as UCoAl are often called quantum itinerant ferromagnets.

The paramagnetic state of UCoAl is sensitive to external magnetic field and pressure, it could be easily changed into ferromagnetic one also by doping. Already a small Ru-Co substitution leads to the ferromagnetic state with ordering temperature strongly depending on the Ru content: T_C = 4.5 K for $UCo_{0.995}Ru_{0.005}Al$ and 16 K for $UCo_{0.99}Ru_{0.01}Al$ [5]. Moreover in the substituted compounds were observed signs of spin fluctuations at low temperatures.

Aim of the experiment:

We intend to investigate the low-energy part of spectrum of $UCo_{0.99}Ru_{0.01}Al$ for first time. According to the bulk properties measurements, we expect to observe some inelastic peaks corresponding to the delicate magnetic order in compound. The experiment would serve as the reference to our planned inelastic neutron scattering experiment under hydrostatic pressure, where we intend to follow the change of magnetic structure as well as corresponding inelastic features in energy spectrum with applied pressure.

Results:

$UCo_{0.99}Ru_{0.01}Al$ single crystal was investigated for the first time employing inelastic neutron scattering techniques.

After sample alignment and verifying the crystal structure parameters, we performed a series of measurements in diffraction condition (k_i = k_f = 1.57 Å^{-1}) with temperature varying between 27 and 1.5 K. The temperature evolution of structural/magnetic reflections -110 and 010 (see Fig. 1) prove the ferromagnetic order below 16 K as determined from magnetization and electrical resistivity measurement.

In the next step, we performed the energy scans around reflections 100, ½½0 and 200 at temperatures 1.5, 15 and 20 K leading to no difference between individual temperatures and leading to no significant features in energy spectra.

The last measurement, performed before the mechanical problem with the A2 motion, was the *h*-scan and *k*-scan around reflection 010 with fixed energy transfer 0.6 and 3 meV at temperatures 1.5 and 20 K (The measurement at latter energy stopped shortly after the start.). This measurement revealed did not reveal any clear inelastic peak in the spectra.

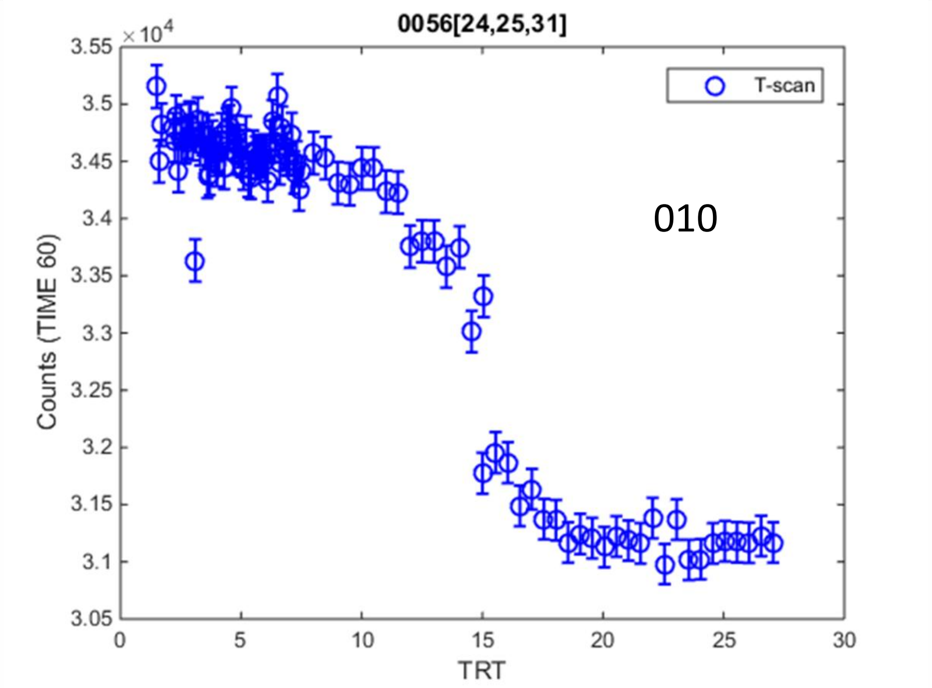

Fig.1 – The temperature evolution of the intensity on structural/magnetic reflection 010. The ordering temperature 16 K is verified.

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[5] P. Opletal, *Critical behaviour in magnetic phase diagrams of uranium compounds*, Master thesis, Charles University in Prague (2015).