Report on the thesis of Martin Míšek

“Magnetic and transport properties of f-electron compounds under extreme conditions”

The manuscript presents important technical developments for high pressure and uniaxial stress generation in hydrostatic conditions accessing various physical properties: AC and DC magnetization, electrical resistivity, heat capacity and neutron diffraction. It presents also studies performed at high pressure at low temperature and under magnetic fields on 3 classes of materials: the RCo_{2-x} family (With R= Er and Ho for the Rare Earth and Si substitution on Co site), UNiGa and Cerium based superconductors such as $CeRh_xPd_{1-x}In_5$ and Ce_2PtIn_8. These studies have been performed on single crystals produced by Czochralski tri arc technique with excellent quality.

The document is divided into five chapters. The first chapter consists in a brief introduction about the interest of pressure techniques in condensed matter physics and the importance of home made development devices for specific measurements. The second chapter presents an overview of the physics related to the localised and itinerant systems and intrinsic phenomena taken place in these compounds associated to the impact of pressure parameters on the physics of localisation and delocalisation. The author makes also here an attempt to extract some general trends of pressure effect on materials based on d and f-elements. The third chapter is really a complete and documented part and is one of the main contributions of the thesis. It describes the devices used, developed and optimised to perform high pressure studies at low temperature and under magnetic field in hydrostatic conditions. The chapter four constitutes the second main part of the document with the experimental results and physics analysis of pressure studies for the mentioned classes of materials. The readers can figure out the effort necessary to establish or improve the magnetic pressure diagrams of the RCo_2 family, the B-T-p magnetic diagrams for UNiGa single crystals and the studies of Ce-115 and Ce-218 superconductors. Finally, a conclusion and a summary of the achieved results constitute the chapter five.

The structure of the manuscript is appropriate and the experimental results are properly documented by figures. Nevertheless, some descriptions of complex phenomena could have been simplified (especially in chapter 4). The written style could have been improved by shortening or splitting sentences which are sometimes too long or very dense. I noticed a certain number of misprints.

The thesis represents a huge amount of experimental work that demonstrates a really impressive technical expertise considering the difficulty of the pressure generation topic at cryogenic temperatures. It is definitely a clear progress for the topic bringing new experience in this domain for the scientific community. Especially, the DAC system and the different tests on transmitting media for magnetic susceptibility as the neutron diffraction diagrams studies under pressure for UNiGa single crystal are really good and new parts. This expertise could be helpful for other applications such as thermal conductivity, thermopower or NMR under pressure. The examination of the RCo_2 systems with the establishment of their pressure diagrams and the observation of change of type of order from 1st to 2nd in properties (magnetization, heat capacity and transport) related to the parimagnetism features developing in these compounds is also a clear and new achievement in the topic. This work is very challenging and could be easily used by comparison to the other reported $CeTIn_5$ superconductor. The author has already 14 papers including some part of this work and several in peer reviewed journals with high impact.

Here are few questions / comments I would like to address:

1) In general, how do you ensure that you know precisely the pressure applied on your materials at intermediate temperatures where you don't have response of your manometer? For instance, in the case of the DAC for susceptibility for instance, you report pressure determination by rubies fluorescence at room temperature and T_c for the lead manometer at low temperature. What about intermediate temperatures? Did you estimate, measure or calibrate the pressure dependence in your devices? In the case of the RCo_2 compounds where the temperature range of interest is around 50-80 K for R=Er based one and 80-150 K for the R=Ho based one, this aspect could be crucial for pressure diagram determination.

2) Do you have an idea of the pressure gradient in the pressure cells around or in the sample (DAC or liquid transmit medium clamp)? The results obtained on the samples are extremely sharp but some features observed could be induced by some inhomogeneities of the pressure distribution especially in the case of the RCo_2 family where the Co sublattices present some selective distribution characteristics in the crystallographic structure. The heat capacity result on $ErCo_2$ is a very nice example: the height of the peak at the transition is varying clearly and passes by a maximum. Could you comment on that?

3) Could you propose another technique to corroborate the pressure effect on the parimagnetism features for the $ErCo_2$ and $HoCo_2$ systems and doped systems?

4) Is there any compression determination by XRD under pressure for instance for these materials ($ErCo_2$ and $HoCo_2$)? This would be then very interesting to analyse the pressure dependency of the several magnetic transition temperature by the Grüneisen coefficients determination.

5) For Ce_2PtIn_8 under pressure, there is no ambient pressure transport curve for comparison presented. According references [98, 99], the ordering temperatures are 2.1 and 2 K, respectively instead of 1.8 and 1.7 K mentioned here. The reference mentioned also that heat capacity results were very reproducible. How do you explain this small discrepancy here? Was the batch fully characterised and did resistivity curve associated reproduce reported features from [98]? The Ce 2-1-8 systems are known to potentially host tiny amount of impurity phases such as $CeIn_3$…

6) The superconducting critical field determination (H_c) under pressure for Ce_2PtIn_8 is very clear and therefore some characteristics can be analysed a little more deeply, such as an estimation of effective mass order from the critical field slope – correlating or not heat capacity measurements - and evolution of $H_c(0)$ with pressure. Could we suppose that the material posses indeed an Hc_2 critical field as type II superconductor? How could you determine or evaluate that? Could you estimate if the sample is in the clean limit?

To conclude, the presented work clearly demonstrates the ability of Martin Misek to perform individual research and to perform creative scientific work. I recommend acknowledging this work as a successful Ph.D. Thesis.

Karlsruhe, 5.12.2012, Dr. Jean-Christophe GRIVEAU