Referee's report on a PhD thesis by

Jaroslav Valenta : « Magnetism in non-centrosymmetric uranium compound : $UIrSi_3$ »

The presented manuscript of the PhD Thesis of Jaroslav Valenta deals with the results of structural and magnetic properties of $UIrSi_3$ compound. This phase is one of the two known uranium compounds crystallizing in non-centrosymmetric structure. These phases have attracted much attention nowadays in the scientific community for the fascinating behaviour of the 5-electrons magnetism of uranium as well as for the possible occurrence of unconventional physical properties. The thesis manuscript has altogether 78 pages and 101 well arranged references. It is well written and clear. Jaroslav Valenta has first prepared polycrystalline samples of $UIrSi_3$ and secondly successfully grown $UIrSi_3$ single crystals by the floating zone mirror method in a four-mirror furnace. Then he devotes his manuscript to a detailed investigation of the transport, thermal and magnetic properties of this interesting compound.

After a short introduction to the topic and presentation of the main motivation of the study, the second chapter is devoted to a short but clear presentation of the theoretical background and formalism of the magnetism and magnetic interactions in 4f and 5f systems. The basic elements of solid state physics theory are also briefly summarized, thus providing the relations necessary to interpret the experimental investigation of the physical properties.

The third chapter gives a description of the numerous experimental methods used by Jaroslav Valenta during his PhD starting from the sample synthesis. This is followed by the techniques used for characterizing bulk samples: X-ray diffraction on both polycrystalline and single crystal samples as well as determination of the intrinsic physical properties at low temperature and under applied magnetic field (electrical transport properties, magnetic measurements, specific heat and dilatometry measurements…). An emphasis is also given to the description of the various high pressure techniques used in this work since these techniques are at the heart of this research work. The main technologies available in Prague at the Material Growth and Measurement Laboratory or developed at the Institute of Physics are described followed by the presentation of the Bridgman anvil pressure cell designed in Osaka University (Japan). The last section of this chapter is devoted to basics elements of neutron scattering theory.

The state of the knowledge of the $UIrSi_3$ compound is presented in the introduction of chapter four. A more detailed description of the unique crystal structure of $UIrSi_3$ compound would have been a useful addition to this presentation focussing mainly on the physical properties. After growth of the single crystal samples, Jaroslav Valenta determines the intrinsic physical properties of $UIrSi_3$, a compound exhibiting an anomaly of specific heat at 41.7K corresponding to a second-order phase transition to an antiferromagnetic state. Both resistivity and magnetic susceptibility measurements present large anisotropic effect. What is the temperature dependence of the resistivity? Is it a classical behaviour? Very unusual cross over of the *a* and *c*-axis reciprocal susceptibility curves is observed at about 93K. I would like Jaroslav Valenta to comment on the shape of the inverse magnetic susceptibility for the two inequivalent crystallographic directions, and the choice of such large magnetic field for the measurements. What is, or could be, the origin of the large difference of the effective magnetic moments and the paramagnetic temperatures derived from the c and a axis?
I suggest that Jaroslav Valenta gives a comparison of the Sommerfeld coefficient obtained in $UIrSi_3$ with other uranium systems or else with normal metals like Cu.
A large anisotropy field of about 59T is estimated by Jaroslav Valenta from the magnetization curves. At 2K linear paramagnetic type behaviour is observed along the a-axis whereas along the easy *c*-axis direction, a saturation can be reached after a first order metamagnetic transition. The hysteretic behaviour observed at low temperature on the magnetization curves is confirmed from specific heat measurements as well as magnetotransport properties. On the basis of a systematic study of temperature and magnetic field dependence of the both specific heat, magnetization curves and electronic transport properties, Jaroslav Valenta draws a magnetic phase diagram of $UIrSi_3$ compound. A remarkable tricritrical point is found at 28K and 5.8T and the ground state of the $UIrSi_{3to}$ compound is assigned to an Ising type antiferromagnet. Jaroslav Valenta also interprets the existence of sharp steps in the magnetization, specific heat, electric resistivity and Hall resistivity as resulting from a Lifshitz transition involving a Fermi surface reconstruction in $UIrSi_3$ compound.
The second part of chapter four is devoted to the investigation of the pressure effect on $UIrSi_3$ single crystals. Studying resistivity and magnetoresistance under pressure up to 6 GPa, Jaroslav Valenta deduces the magnetic phase diagram evolution versus pressure. Magnetization curves recorded along the c axis under applied pressure reveal a weak pressure

dependence. The critical field is almost insensitive to pressure. The pressure effects on the magnetic properties are analysed in the light of compressibility measurements indicating that *a* is an easier compression axis than the *c* axis. Jaroslav Valenta consequently suggests some possible interpretations of the observed behaviour. To conclude on this chapter presenting numerous experimental results carried out in extreme conditions of temperature, magnetic field and pressure, it leads to a complex but interesting magnetic phase diagram.

Neutron measurements have been carried out by Laue as well as 4-circles diffractometry techniques at the Institut Laue Langevin, Grenoble (France). The crystal structure $UIrSi_3$ compound has been confirmed from the nuclear diffraction data but no details are given here. This neutron diffraction has been carried out on $UIrSi_3$ single crystal aiming to investigate the magnetic structure of this compound. The obtained magnetic propagation vector is (0.1, 0.1, 0) and it's temperature dependence as well as it's evolution versus applied magnetic field are revealed. The exact magnetic structure is found to be too complex to be solved at this stage.

As an evaluation, I can state that the applicant succeeded to prepare $UIrSi_3$ single crystals, to determine their physical properties using contemporary experimental methods and appropriate data treatments. The manuscript presented by Jaroslav Valenta is a useful and important contribution to the study of the remarkable physical properties of this $UIrSi_3$ intermetallic compounds. He has revealed the details of the complex magnetic phase diagram of this compound. Investigations of the transport properties as well as the magnetic properties studies have been done carefully and the results convincingly discussed in the text.

At this stage of his career, Jaroslav Valenta has already published 12 articles in international peer-review journals two of which are dealing with $UIrSi_3$ compounds whereas others are focussed on the magnetic properties of other intermetallic compounds. Jaroslav Valenta is the first author of several scientific papers. These articles have several co-authors showing the ability of the applicant to participate in effective collaborations. In addition, he has spent several weeks abroad, in particular at Tohoku University, to get experience on the use of Bridgeman-type high pressure cells.

For all these reasons I can state that the candidate definitely presented the ability to conduct the difficult experimental research and the dissertation can be accepted.

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