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ScienceDirect

Physica B 403 (2008) 1365–1367

PHYSICA B

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First order magnetic transition and magnetoelastic effects in Sm_2IrIn_8

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Abstract

We report measurements of temperature dependent heat capacity, thermal expansion and high resolution X-ray diffraction (XRD) taken on single crystals of Sm_2IrIn_8 intermetallic compound. This compound belongs to the $R_mM_nIn_{3m+2n}$ family (R = rare earth, $m = 1$, 2, $n = 0$, 1 and M = Rh, Ir and Co) which includes a number of heavy fermion superconductors for R = Ce. Particularly, Sm_2IrIn_8 is the only member of this family to present a first order magnetic phase transition (FOMT). Both thermal expansion and heat capacity data show very pronounced sharps peaks at $T_N = 14.2\,K$ consistent with an FOMT. The linear thermal-expansion coefficient is anisotropic and both *c*-axis and basal *ab* plane coefficients change discontinuously at 14.2 K. This change is negative for both direction in contrast to what was found for other members of family such as Ce_2RhIn_8 and $CeRhIn_5$. The zero-field high resolution XRD data at 14.2 K shows no evidence for a tetragonal-to-orthorhombic structural phase transition. We discuss our results considering tetragonal crystalline field effects (CEF), quadupolar interactions, antiferromagnetic domains and magnetoelastic effects.

PACS: 75.30.Kz; 75.30.−m; 71.27.+a

Keywords: First order magnetic phase transition; Magnetotrictive effects; CEF effects

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To understand the role of dimensionality, magnetic anisotropy and crystal field effects (CEF) in the evolution of the physical properties of Ce_mMIn_{3m+2} family ($m = 1, 2$, M = Rh, Ir and Co), where the superconducting state seems to be magnetically mediated, the study of the antiferromagnetic structurally related relatives continues to be an important subject to explore. The bi-layer member of this family, Sm_2IrIn_8 presents a first order magnetic phase transition (FOMT) at $T_N = 14.2\,K$ and an additional anomaly at $T \sim 11.5\,K$ for which a microscopic origin has not been identified [1]. Commonly, FOMT is driven/accompanied by lattice distortion derived from strong spin–orbit coupling associated with crystalline electrical field and/or magnetoelastic effects. Here we present the results of thermal expansion coefficient measurements, heat capacity and a high resolution X-ray diffraction (XRD) study to further investigate to possible origin of the FOMT in Sm_2IrIn_8.

Single crystalline samples of Sm_2IrIn_8 were grown from the melt of In flux as described previously [2] and checked by X-ray powder diffraction. The thermal expansion experiments were performed using a capacitance dilatometer with a resolution $\leqslant 1\,Å$. The single crystal XRD experiments were carried out at XRD2 beamline of the Brazilian Synchrotron Light Source (LNLS) [3]. The incident photon energy used was 10 keV.

Fig. 1(a) shows the linear thermal-expansion coefficient $\alpha = (1/L)(dL/dT)$ for Sm_2IrIn_8, taken between $2 \leqslant T \leqslant 21\,K$, along *c*-axis and the basal *ab* plane. α is highly anisotropic and it changes discontinuously around 14.2 K. Interestingly, this change is negative in both cases, unlike what was observed for both $CeRhIn_5$ [4] and Ce_2RhIn_8 [5]. Two additional features are observed around 11 and

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doi:10.1016/j.physb.2007.10.151

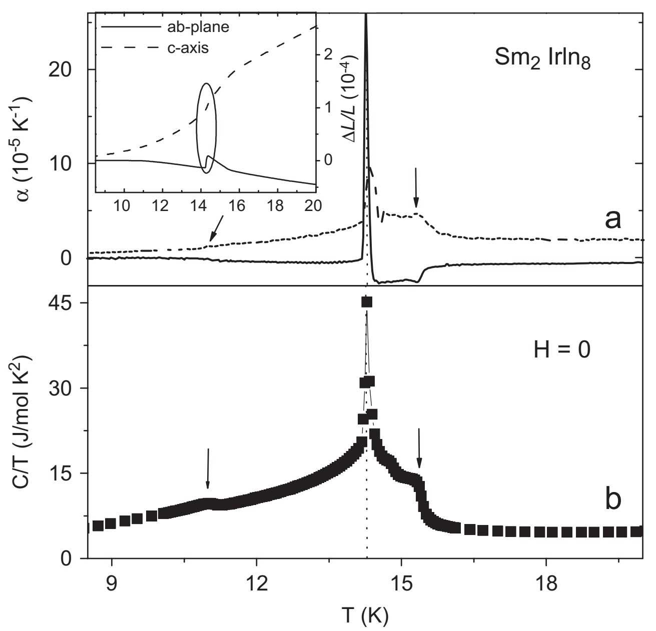

Fig. 1. (a) Thermal-expansion coefficient, $\alpha = (1/L)(dL/dT)$, along *ab* plane (continuous line) and *c* (dashed curve) directions. Arrows show the different features observed. Inset: expansivity $\Delta L/L$ for both axis (circle shows the sharp contraction in T_N for both cases). (b) Specific heat data with zero applied field [1] showing the same features appearing in (a).

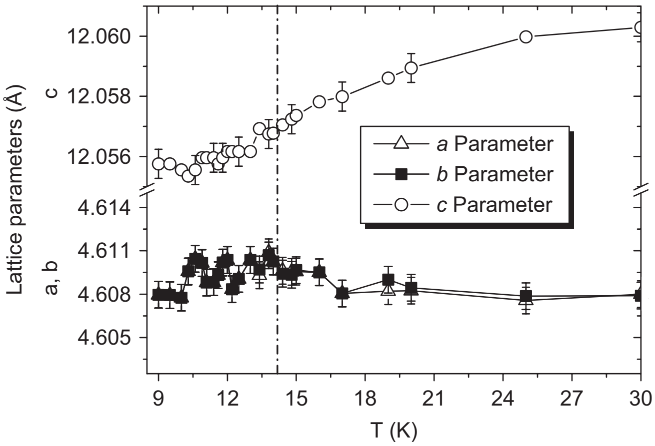

Fig. 2. The three lattice parameters *a*, *b* and *c* extracted from longitudinal scans of the (1, 0, 9), (0, 1, 9) and (0, 0, 7) peaks, respectively, in the temperature range $9 \leqslant T \leqslant 30$ K for Sm_2IrIn_8.

15.3 K. The main peak in Fig. 1(a) is at least one order of magnitude larger than in $CeRhIn_5$, consistent with an FOMT in Sm_2IrIn_8 [1]. The high-*T* anomaly observed in the paramagnetic region above T_N (at $T \sim 15.3$ K) may be associated with a quadrupolar ordering already seen for the cubic $SmIn_3$ compound [6,7]. All the features observed in Fig. 1(a) are consistent with the specific heat data of Fig. 1(b).

In Fig. 2, we show the behavior of *a*, *b* and *c* cell parameters from 20 to 9 K. $\theta - 2\theta$ scans at the (1, 0, 9), (0, 1, 9) and (0, 0, 7) peaks were performed at zero applied field. Since the (*h*, 0, *l*) and (0, *k*, *l*) reflections are equivalent in the tetragonal structure, but not in the orthorhombic one, we expect a separation in the reciprocal space positions (2θ) if a magnetoelastic distortion is taking place at T_N. These results show that there is no split between *a* and *b* parameters below T_N, and therefore the tetragonal structure remains stable for all the temperature range studied.

According to our recent X-ray magnetic scattering (XRMS) results [8] for study of the magnetic structure of Sm_2IrIn_8, the Sm ordered moments are in *ab* plane and $T_N = 14.2$ K is slightly decreased compared to T_N for the cubic precursor $SmIn_3$, which is in agreement with a general CEF trend found within the R_mMIn_{3m+2} family [9,10].

The magnetic order of the cubic parent $SmIn_3$ develops in a Γ_8 quartet crystal-field ground state and possesses strong intrinsic quadrupole moment leading to additional interactions which order the quadrupoles [6,11,12]. The insertion of two layers of $SmIn_3$ along *c* in Sm_2IrIn_8 splits the Γ_8 quartet into two doublets and the new CEF scheme and wave-function can modify both the bilinear and quadrupolar interactions. This may tune the balance between the two classes of interaction causing not only changes in T_N [9,10] but also in the nature of the magnetoelastic effects. It has been shown that in some cases (see, for example, Ref. [13] on DySb) the spin and quadrupole ordering temperature could merge together with the magnetic structure being fixed by quadrupolar interactions, which are then responsible for the first order character of the transition, driving a magnetoelastic structural transition to lower symmetries (e.g. tetragonal-to-orthorhombic) [14,15].

However, in the zero field data of Fig. 2 we did not find any tetragonal-to-orthorhombic magnetoelastic transition. One possible explanation for this is the recent observation [8] of symmetry-related reflections of type ($\frac{1}{2}$, 0, *l*) and (0, $\frac{1}{2}$, *l*), corresponding to a twinned magnetic structure [propagation vector ($\frac{1}{2}$, 0, 0)] indicating the presence of antiferromagnetic domains for Sm_2IrIn_8 when the materials are zero-field-cooled to ordered state. The presence of such domains can hide the tetragonal-to-orthorhombic magnetoelastic distortion, as *a* and *b* are switched between the domains. Further high resolution XRD measurements in the field cooling regime for Sm_2IrIn_8 are planned to confirm this supposition.

We thank the financial support of CNPq, FAPESP and ABTLuS in Brazil, and at Los Alamos the U.S. Department of Energy.

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