
15 May 2002

Magnetic and Neutron Diffraction Studies on PrMnSb₂

Satish K. Malik

Zili Chu

Amish G. Joshi

Jinbo Yang

et. al. For a complete list of authors, see https://scholarsmine.mst.edu/phys_facwork/221

Follow this and additional works at: https://scholarsmine.mst.edu/phys_facwork

 Part of the [Chemistry Commons](#), and the [Physics Commons](#)

Recommended Citation

S. K. Malik et al., "Magnetic and Neutron Diffraction Studies on PrMnSb₂," *Journal of Applied Physics*, vol. 91, no. 10, pp. 7842-7844, American Institute of Physics (AIP), May 2002.
The definitive version is available at <https://doi.org/10.1063/1.1453938>

This Article - Journal is brought to you for free and open access by Scholars' Mine. It has been accepted for inclusion in Physics Faculty Research & Creative Works by an authorized administrator of Scholars' Mine. This work is protected by U. S. Copyright Law. Unauthorized use including reproduction for redistribution requires the permission of the copyright holder. For more information, please contact scholarsmine@mst.edu.

Magnetic and neutron diffraction studies on PrMnSb₂

S. K. Malik

Tata Institute of Fundamental Research, Colaba, Mumbai 400-005, India

Z. Chu^{a)}

Department of Physics, University of Missouri-Columbia, Columbia, Missouri 65211

Amish G. Joshi

Tata Institute of Fundamental Research, Colaba, Mumbai 400-005, India

J. B. Yang and W. B. Yelon

Graduate Center of Materials Research and Departments of Chemistry and Physics, University of Missouri-Rolla, Rolla, Missouri 65409

Q. Cai

Department of Physics, University of Missouri-Columbia, Columbia, Missouri 65211

W. J. James

Graduate Center of Materials Research and Departments of Chemistry and Physics, University of Missouri-Rolla, Rolla, Missouri 65409

K. Kamaraju

Department of Physics, University of Missouri-Rolla, Rolla, Missouri 65409

Magnetic and neutron diffraction studies have been carried out on PrMnSb₂. Magnetization data in the temperature range of 5–400 K show two magnetic transitions: one at ~175 K attributed to the antiferromagnetic ordering of the Mn moments, and the other at ~35 K possibly due to the antiferromagnetic ordering of the Pr moments. The magnetization-field isotherms at various temperatures are consistent with the above. Neutron diffraction data obtained at various temperatures can be fitted with a nearly antiferromagnetically coupled Mn moment of ~3 μ_B at 70 K. At 10 K, moments both on Mn (~3.5 μ_B) and Pr (~0.94 μ_B) are ordered antiferromagnetically with small canting angles. © 2002 American Institute of Physics. [DOI: 10.1063/1.1453938]

I. INTRODUCTION

Ternary rare earth intermetallic compounds with the general formula RMnSb₂ (R=La, Ce, Pr, Nd, and Sm) crystallize in the tetragonal ZrCuSi₂ type structure (space group *P4/mmm*, No. 129). These show magnetic ordering of the Mn moments in the temperature range of 100–520 K.¹ Furthermore, the rare earth sublattice also appears to order magnetically below 50 K in the abovementioned compounds with Ce, Pr, and Nd. The Mn–Mn distance in these compounds is large enough to induce ferromagnetic interaction in them reminiscent of the Mn-based Heusler alloys. We have started a systematic investigation of the magnetic structure of these compounds using magnetization and powder neutron diffraction studies. We present here the results of such studies on PrMnSb₂.

II. EXPERIMENTAL DETAILS

The compound PrMnSb₂ was prepared by melting together of the stoichiometric amounts of the constituent elements in a radio frequency induction furnace under a continuous flow of argon gas. The sample was turned over and melted several times. Subsequently, it was annealed at 850 °C for seven days and furnace cooled to room temperature. Powder x-ray diffraction patterns were obtained using

Cu *K* α radiation. Magnetization measurements on PrMnSb₂ were carried out in the temperature range of 5–400 K and in applied fields up to 55 kOe using a SQUID magnetometer (quantum design). Magnetization-field hysteresis loops were also recorded at various temperatures. Neutron diffraction patterns were obtained at temperatures of 300, 200, 70, and at 10 K, using the high resolution powder neutron diffractometer at the University of Missouri Research Reactor Facility with neutrons of wavelength 1.4875 Å.

III. RESULTS AND DISCUSSION

Powder x-ray diffraction studies reveal that PrMnSb₂ is nearly single phase with a small amount of PrSb. This is also verified from neutron diffraction studies. Rietveld refinement of the room temperature neutron diffraction data yields about 8% PrSb by weight. The PrMnSb₂ compound crystallizes in the tetragonal ZrCuSb₂ type structure. The lattice parameters and other structural details are given in Table I. Refinement of the site occupancies also suggests some Mn deficiency consistent with the earlier observation that these compounds form with reduced Mn content.¹ In this article, we will continue to refer to this compound by its nominal stoichiometry.

Figure 1 shows the plot of magnetization versus temperature for PrMnSb₂ measured in an applied field of 5 kOe. Two magnetic transitions are clearly visible—one at around 175 K and the other around 35 K (along with a broad shoulder). It is reasonable to attribute the higher of the two tran-

^{a)}Electronic mail: zc58f@mizzou.edu

TABLE I. Lattice parameters and magnetic moment values in PrMnSb₂. Uncertainty on each quantity are given in parentheses.

Temp.	10 K	70 K	200 K	300 K
a (Å)	4.29794(23)	4.29897(25)	4.308132(22)	4.31516(25)
c (Å)	10.68809(58)	10.69018(59)	10.69847(63)	10.70586(63)
χ^2	2.76	2.59	2.61	2.88
Mn_vac %	10.3(8)%	10.3(8)%	10.3(8)%	10.3(8)%
wt. frac.	91.9(15)%	91.90(15)%	91.9(15)%	91.9(15)%
wt. frac.	8.1(5)%	8.1(5)%	8.1(5)%	8.1(5)%
PrSb				
Propagation	(0,0,0.5)	(0,0,0.5)	(0,0,0)	(0,0,0)
	$M_z(\mu_B)$ $M_{xy}(\mu_B)$	$M_z(\mu_B)$ $M_{xy}(\mu_B)$	$M_z(\mu_B)$ $M_{xy}(\mu_B)$	$M_z(\mu_B)$ $M_{xy}(\mu_B)$
Pr(1/4,1/4,0.73)	-0.899(48) 0.261(14)			
Pr(3/4,3/4,-0.73)	-0.899(48) -0.261(14)			
Mn(3/4,1/4,0)	1.893(41) 2.965(65)	1.338(24) 2.729(48)		
Mn(1/4,3/4,0)	1.893(41) -2.965(65)	1.338(24) -2.729(48)		

sitions to the magnetic ordering of the Mn moments while the lower transition may possibly be due the ordering of the Pr moments. The peaks in the magnetization data suggest these to be transitions to the antiferromagnetic state. No other transition is visible in the temperature range of 5–400 K. Sologub *et al.*¹ reported a magnetic transition at about 390 K in their PrMn_{0.82}Sb₂ sample. However, none are seen at that temperature in our sample.

Figure 2 shows the magnetization (M) applied field (H) hysteresis loops at various temperatures in applied fields up to 55 kOe. At 5 K, where both Pr and Mn moments are presumed to be magnetically ordered, the $M-H$ loop deviates only slightly from linear variation expected for an antiferromagnetic ordering of the moments. The small deviation from linearity may be either due to canting of moments or due to the onset of applied field-induced spin reorientation. The $M-H$ loop at 100 K (where only Mn moments are ordered) is a straight line typical of antiferromagnetic systems. The $M-H$ loops at 250 and 400 K largely exhibit a straight-line behavior on which a very small ferromagnetic component is superposed. At present it is not clear whether the

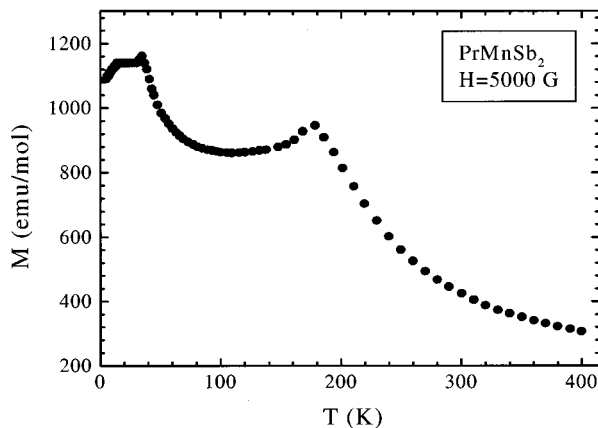


FIG. 1. Magnetization vs. temperature for PrMnSb₂ in an applied field of 5 kOe.

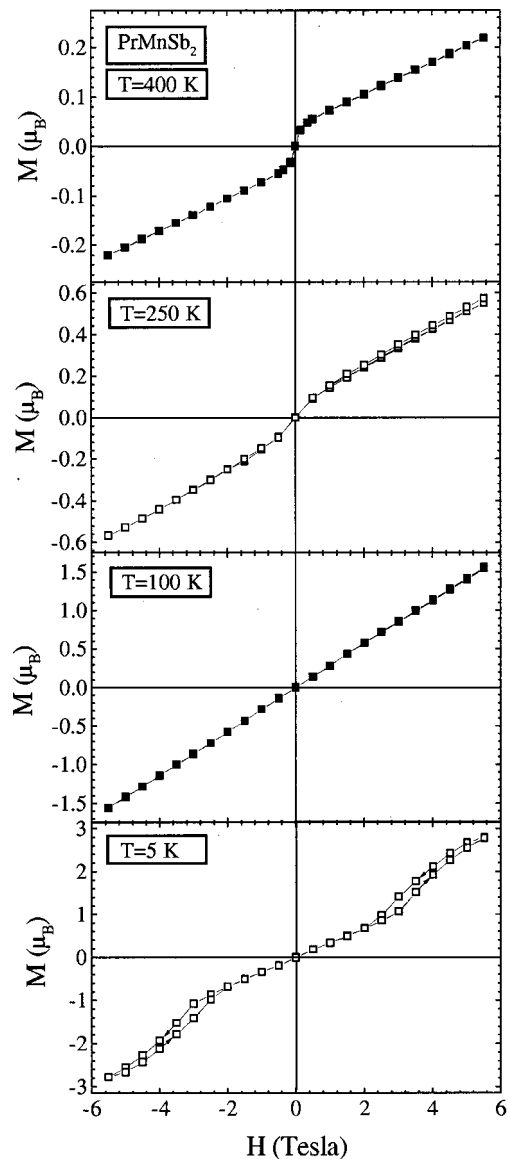


FIG. 2. Magnetization-field hysteresis plots for PrMnSb₂ at various temperatures.

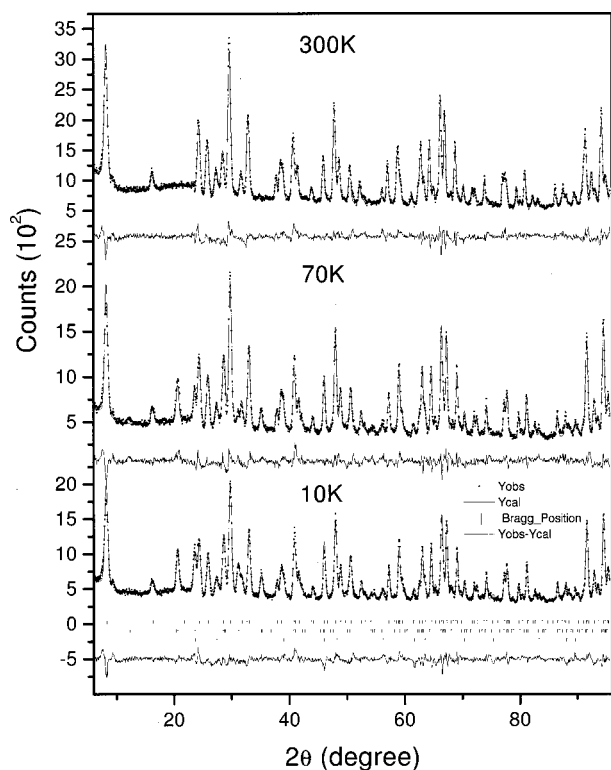


FIG. 3. Refined powder diffraction patterns for PrMnSb_2 at various temperatures. The upper tic mark is nuclear structure of PrMnSb_2 , middle is antiferromagnetic phase of PrMnSb_2 , and lower is nuclear structure of PrSb .

ferromagnetism is intrinsic or due to the presence of some impurity phases. Formation of PrSb as an impurity phase in PrMnSb_2 suggests that a very small amount of MnSb phase may also be present in this compound (based on stoichiometry). The MnSb phase is known to order ferromagnetically with a Curie temperature of about 573 K (Ref. 2) and its presence may lead to some nonlinearity in the $M-H$ curves at 250 and 400 K. Extension of magnetization studies to higher temperatures is desirable.

The 300 K neutron diffraction (ND) pattern can be analyzed without any magnetic moment on Mn ions. The 10 and 70 K data show several extra peaks, see Fig. 3, which indi-

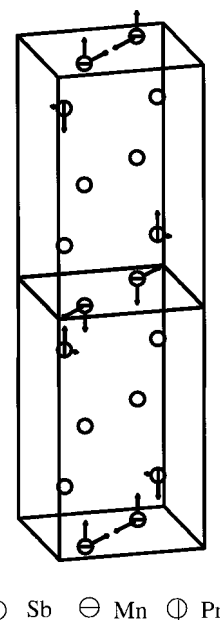


FIG. 4. Magnetic structure of PrMnSb at 10 K. The magnetic unit cell is doubled along the c axis with respect to the crystallographic cell.

cated the antiferromagnetic ordering. The magnetic structure is modeled with propagation vector $(0,0,0.5)$. This doubles the unit cell along z . Each magnetic site in the lower half of the magnetic unit cell has a counterpart in the upper half with antiparallel alignment. Analysis of the 70 K ND pattern yields a magnetic structure in which Mn ion moments are antiferromagnetically ordered and have a value of $\sim 3\mu_B$. The 10 K diffraction pattern is analyzed on the basis of magnetic ordering of both the Pr and the Mn moments. The magnetic ordering appears more complex (Fig. 4) with Pr and Mn sublattices ordered antiferromagnetically (with different canting angles) and with moment values of $\sim 3.5\mu_B$ at the Mn site and $0.94\mu_B$ at the Pr site. The results of structural and magnetic refinements are largely summarized in Table I.

¹O. Sologub, K. Hiebl, P. Rogl, and O. Bodak, *J. Alloys Compd.* **227**, 40 (1995).

²See, for instance, W. Reimers, E. Hellner, W. Treutmann, and G. Heger, *J. Phys. C* **15**, 3597 (1982).