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Magnetic properties and structure of MnPtAl

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Abstract

The magnetic properties of the intermetallic compound MnPtAl were studied by means of low- and high-field magnetisation, magneto-resistance and neutron diffraction. The high-field magnetisation at 4.2 K reveals a metamagnetic transition around 30 T which is accompanied by a drastic drop in electrical resistivity. From neutron diffraction we find antiferromagnetic order below 300 K with the Mn moments perpendicular to the *c*-axis.

Keywords: Magnetoresistance; First order magnetisation process

Equiatomic ternary Mn compounds of the type MnTX, where T is a late transition metal element and X an s,p-metal, often form in the Heusler C1_b type of structure or the CaIn₂ type of structure [1,2]. From this group of compounds MnPtSb has attracted most attention as it shows a huge magneto-optical Kerr effect [1,3]. Most of these compounds order magnetically with rather high ordering temperatures reaching 730 K for MnNiSb. We have reinvestigated the magnetic properties of the compound MnPtAl crystallising in the hexagonal Ni₂In structure, which was qualified in Ref. [2] as a Pauli paramagnet. On the other hand the isostructural and isoelectronic compound MnPtGa, with only slightly larger lattice parameters, was found to order ferromagnetically at *T*_c = 220 K. The high-temperature (*T* > 500 K) magnetic susceptibility of MnPtAl displays Curie–Weiss behaviour with a rather large ferromagnetic θ_p = 270 and an effective moment of 3.6 μ_B per Mn atom. The absence of magnetic order in MnPtAl, in contrast to MnPtGa, was attributed to random occupation of the three available lattice sites suggested by X-ray results [4].

We have studied the magnetic, magneto-transport and crystallographic properties of the compound MnPtAl by measuring the temperature dependence of the magnetisation and electrical resistivity, magnetisation and resistivity in high-magnetic fields and by neutron diffraction. The temperature dependence of the low-field (0.5 T) magnetisation measured from 1.8 to 300 K in a SQUID magnetometer, is in good agreement with the results of Ref. [2],

showing a broad but shallow maximum around 200 K and a slight upturn towards the lowest temperatures. The temperature dependence of the electrical resistivity measured with a standard ac 4 point method from room temperature down to 4.2 K, does not show any pronounced features. However, the high-field magnetisation measured in the Amsterdam High-Field Installation [5] at 4.2 K (Fig. 1) reveals a metamagnetic transition centred at 30 T. This transition displays hysteresis, when measured with increasing or decreasing field, with a width of about 0.5 T. Above this transition the magnetisation is not yet saturated and at 38 T a magnetisation of 2.5 μ_B per formula unit is found. The field dependence of the resistivity measured in the same installation on a polycrystalline sample with the field applied parallel to the current direction is displayed in Fig. 2. After an initial drop the resistivity increases with increasing field to a value 5% larger than the zero-field value, which may be expected for a paramagnetic material. However, at the field of the metamagnetic transition the

Fig. 1. High field magnetisation of MnPtAl at 4.2 K (squares taken in static fields, lines taken during a field sweep).

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Fig. 2. Field dependence of the electrical resistivity at 4.2 K.

resistivity steeply drops, leading at 35 T to a 25% reduction in electrical resistivity compared to the zero-field value. It should be noted, the magneto-resistivity data have always been taken with decreasing field, thus hysteresis is not expected to occur.

To clarify this peculiar magnetisation and magneto-resistivity behaviour we performed neutron diffraction experiments on the multidetector DN5, at the Siloe reactor of CEN-Grenoble. The crystallographic structure was determined at a wave length of 1.34 Å at 300 K. Rietveld analysis of the diffraction pattern reveals that MnPtAl forms in the hexagonal Ni_2In structure, space group 194, with $a = 432.55$ pm and $c = 549.65$ pm. The manganese, platinum and aluminium atoms occupy the 2a, 2d and 2c sites respectively. The profile and Bragg R -factors are found to be 4.4 and 4.7%, respectively. The magnetic order was investigated from 1.8 to 310 K at a wave length of 2.49 Å.

From the appearance of the (001) reflection below about 295 K, which is a forbidden nuclear reflection in this structure type, it follows that MnPtAl orders antiferromagnetically below this temperature.

From the magnetic intensities it follows that the Mn moments are oriented normal to the c -axis, with a maxi-

Fig. 3. Temperature dependence of the staggered magnetisation.

mum moment of $3.7 \mu\text{B}/\text{Mn}$ atom at 1.8 K [6]. The temperature dependence of the staggered magnetisation is shown in Fig. 3. The 1.5% reduction in unit-cell volume must thus be responsible for the drastic difference in the magnetic properties between MnPtGa and MnPtAl.

These results can be understood in terms of the strong Mn–Mn distance dependence of the Mn–Mn exchange interaction [7]. Large Mn–Mn distances favour ferromagnetic coupling of the Mn moments, while small Mn–Mn distances favour antiferromagnetic coupling. This interplay between lattice dimensions and magnetism plays an important role in controlling the temperature dependence and the field dependence of the magnetisation. The magnetic ordering of MnPtAl occurs at a fairly low temperature where the Mn–Mn distance is sufficiently small for prevailing antiferromagnetic coupling. Due to the thermal expansion of the lattice, above 500 K ferromagnetic interactions become dominant and lead to the ferromagnetic-like Curie Weiss behaviour [4]. In Fig. 1, it is seen that the antiferromagnetic coupling of the moments is broken when applying a magnetic field of 30 T or larger. The hysteretic character of this transition indicates that it is of first order. The large hysteresis is very likely caused by the strong interplay between moment coupling and lattice dimensions. In other words, the hysteretic nature of this metamagnetic transition is most probably caused by a large magnetovolume effect [8]. It is reasonable to assume that the combined change of magnetic and lattice properties will alter the Fermi surface and thus give rise to the steep change in resistivity observed.

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