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Magnetic properties of Dy_5Pd_2 single crystal

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Thermal variation of the lattice parameters, magnetic susceptibility and magnetization of a Dy_5Pd_2 single crystal has been measured. The single crystal obtained by the Czochralski method crystallized in the cubic Dy_5Pd_2 type structure. The compound exhibits two characteristic temperatures. The former equals about 40 K, and the latter about 20 K, being connected with the complex ordering of the rare earth sublattice and the reorientation process of the magnetic moments, respectively.

Key words: *rare earth–transition metal compound; single crystal; lattice parameters; magnetic susceptibility*

1. Introduction

The R_5Pd_2 intermetallic compounds were investigated by Berkowitz et al. [1]. They reported the existence of four new R_5Pd_2-type (R = Gd, Tb, Dy, Ho) compounds. All these compounds crystallize in the cubic Dy_5Pd_2-type crystal structure belonging to the space group *Fd*3*m* [2]. Recently, magnetic properties of R_5Pd_2 (R = Tb, Dy, Ho, Er) intermetallic compounds were examined [3]. The samples were obtained in a polycrystalline form by induction melting. The electrical resistivity as well as ac and dc magnetic susceptibility measurements show a complex transport and magnetic behaviour of these compounds. The aim of this work was to grow a good quality single crystal of Dy_5Pd_2 and to examine the thermal variations of its lattice parameter as well as its magnetic properties.

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2. Experimental

The single crystal was obtained by the Czochralski method from a levitated melt using high purity starting materials. The structure of the "as-grown" crystal was examined by the X-ray Berg–Barrett topography using FeK_α radiation. The lattice parameter of the Dy_5Pd_2 single crystal was studied in the temperature range from 10 K up to 300 K using a multilayer OSMIC monochromator with CuK_α radiation from a Schneider rotating anode and four-circle Huber diffractometer with χ-circle [4]. The diffractometer was controlled by a STADI4 program system and equipped with a two-stage closed-cycle helium-cooling device (CTI-Cryogenics). The temperature was controlled within the accuracy of 0.1 K.

DC magnetic susceptibility and magnetization were measured parallel to the [111] direction in the temperature range 1.9-400 K and in applied magnetic fields up to 5 T using a Quantum Design MPMS (Magnetic Property Measurement System) SQUID magnetometer.

3. Results and discussion

The Berg–Barrett X-ray topography of Dy_5Pd_2 shows that the investigated crystal grew without mosaic structure (Fig. 1). The room temperature lattice constant *a* is 13.53 Å being in good agreement with the value reported in Ref. [2].

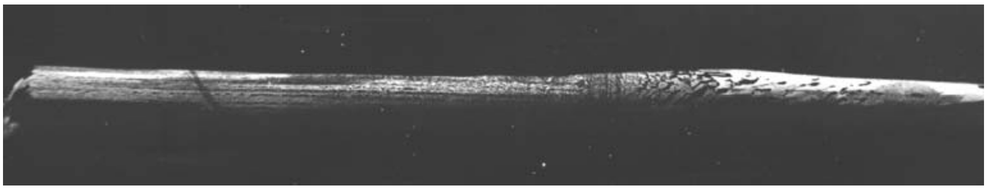

Fig. 1. Berg–Barrett topography of the Dy_5Pd_2 single crystal

Precise measurements of thermal variation of the lattice parameter were carried out for the produced single crystal. The temperature dependence of the unit cell volume *V* is presented in Fig. 2. The unit cell volume *V* decreases in agreement with the Grüneisen–Debye theory on decreasing temperature from 300 down to 50 K. Below the latter temperature, which is close to the magnetic ordering temperature, the contraction of the unit cell volume was observed. The obtained thermal dependence of the unit cell volume was fitted according to the Grüneisen–Debye theory assuming the Debye temperature Θ_D = 180 K (Fig. 2). The linear thermal and volume expansion coefficients α_a and α_V in the temperature range from 150 K to 300 K equal $3.99(14)\times10^{-5}$ K^{-1} and $1.34(4)\times10^{-5}$ K^{-1}, respectively.

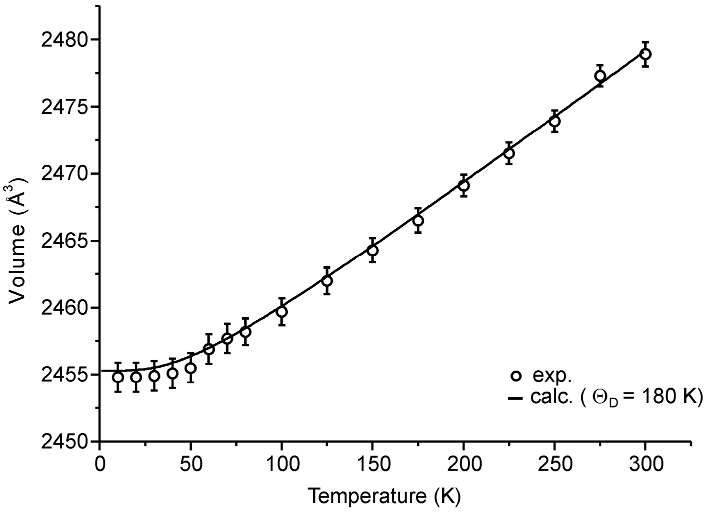

Fig. 2. Thermal variation of the unit cell volume of the Dy_5Pd_2 single crystal

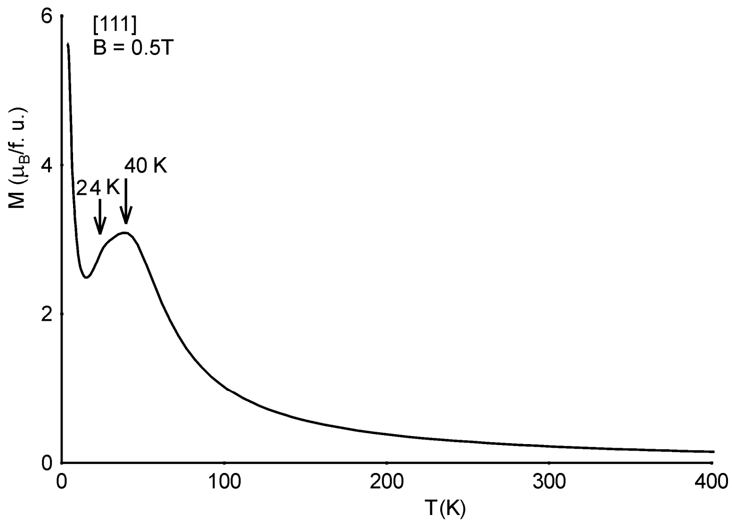

Fig. 3. Temperature dependence of the magnetization for Dy_5Pd_2 single crystal

The temperature dependence of the magnetization susceptibility, measured at the magnetic field of 0.5 T parallel to the [111] direction in the temperature range 1.9–400 K, is shown in Fig. 3. The characteristic feature of this dependence is a wide peak with two contributions: the first one at 40 K is connected with complex ordering of the rare earth sublattice and the second one occurring at 24 K may be attributed to the reorientation process to the magnetic structure with antiferromagnetic contribution. Earlier, similar effects were observed for a polycrystalline sample [3]. Below 14 K a strong increase of the magnetization due to a ferromagnetic arrangement is observed.

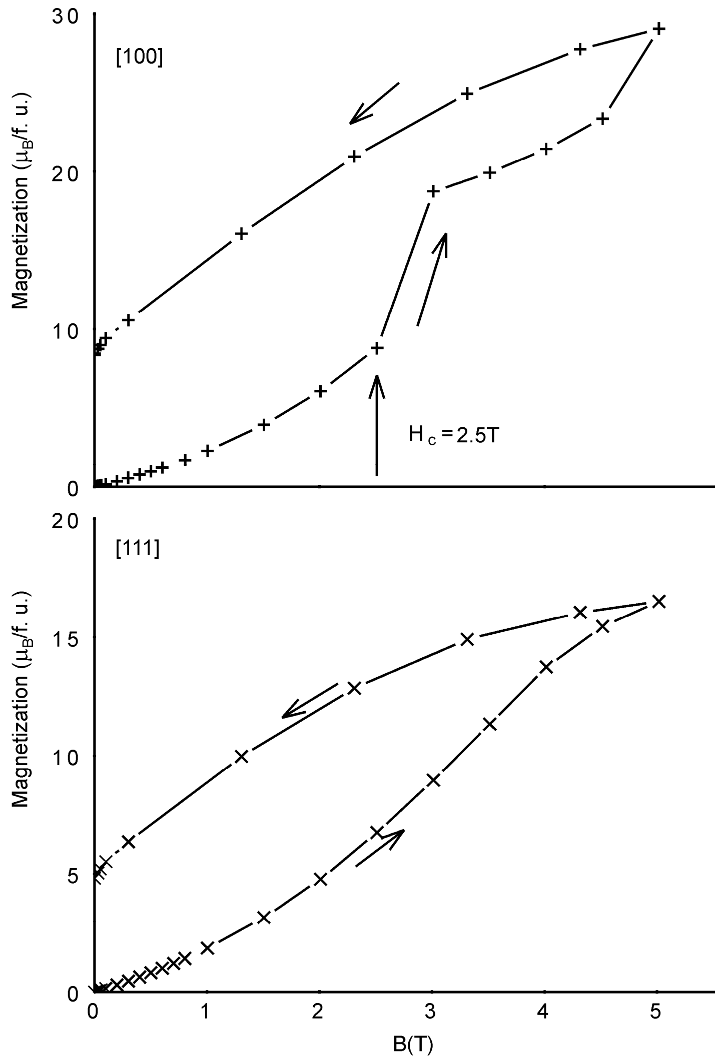

Fig. 4. Magnetization field dependence of Dy_5Pd_2 single crystal measured in different crystallographic directions indicated in the figures

Figure 4 shows the magnetization curve measured at 1.9 K in the magnetic fields up to 5 T. The values of the magnetic moment at 5 T are far from saturation and reach 5.8μ_B for the [100] direction and 3.3μ_B for the [111] direction. The widest hysteresis loops are observed for [111] direction and the value of magnetic remanence is 9μ_B/f.u. For [100] direction we observed narrower hysteresis loops with the value of magnetic remanence of 5μ_B/f.u. (Fig. 4). The hysteresis measured for [100] direction shows the metamagnetic transition at the critical field H_c = 2.5 kOe, while for the [111] direction such a transition has not been observed.

4. Conclusions

A single crystal of Dy_5Pd_2, obtained by the Czochralski method, crystallizes in a cubic crystal structure. This structure is characterized by the large unit cell volume and three non-equivalent dysprosium sites. The dysprosium ions are arranged into triangle configurations. This might lead to frustration effects that may be modified by the palladium contribution to the conduction band.

References

[1] BERKOWITZ A.E., HOLTZBERG F., METHFESSEL S., J. Appl. Phys., 35 (1964), 1030.
[2] FORNASINI M.L., PALENZONA A., J. Less Common Metals, 38 (1974), 77.
[3] KLIMCZAK M., TALIK E., WINIARSKI A., TROĆ R., J. Alloys Comp., 423 (2006), 62.
[4] KUSZ J., BÖHM H., J. Appl. Crystall., 35 (1002), 8.

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