Magnetic and transport properties of the narrow-gap semiconductor Yb_5Si_4

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We report the synthesis and basic properties of the binary compound Yb_5Si_4, which crystallizes in the orthorhombic Gd_5Si_4-type structure (space group *Pnma*) [1]. The polycrystalline sample has been prepared by using an encapsulated metal crucible. The crucible is slowly heated up to 1800 °C, using a high-frequency induction furnace. The magnetic susceptibility follows the Curie-Weiss law above 50 K; the effective magnetic moment per Yb ion is determined to be 2.9 μ_B. Considering the reasonable ratio of Yb^{3+} and Yb^{2+} from the value of the effective moment, it is estimated to be Yb^{3+} : Yb^{2+} = 2 : 3. There are a total of 20 Yb atoms per unit cell distributed among three crystallographic sites, the multiplicity of which is Yb1 : Yb2 : Yb3 = 4 : 8 : 8. Assuming that 8 of 20 Yb atoms in each unit cell are in the Yb^{3+} state, and 12 are in the Yb^{2+} state, the ratio of Yb valence can be explained. The existence of magnetic ordering at low temperatures has previously been indicated by ^{170}Yb Mössbauer spectroscopy measurements [2]. The clear lambda-type anomaly has been observed at 1.6 K from the specific measurement, suggesting a long-range magnetic ordering. The extended high temperature tail in the temperature dependence of the specific heat between 1.6 and 10 K has been observed. This anomaly seems to be related to the development of magnetic correlations. The magnetic entropy evaluated from the specific heat data is only similar to 2/5 of the Rln2 per mole of Yb_5Si_4 around 10 K. The value of magnetic entropy taking into account the ratio of Yb valence implies that the crystalline electric field (CEF) ground state of Yb^{3+} ions is a Kramers doublet. Electrical resistivity measurements on Yb_5Si_4 reveal a semiconducting behavior at all temperatures. The small energy gap of 440 K has been obtained at room temperature estimated by the thermal activation model. The energy gap gradually decreases with decreasing temperature, and finally reaches 1 K or less.

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