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Letter

Antiferromagnetic ordering in $PrCu_2Si_2$, $PrCu_2Ge_2$ and $TbCuSi_2$

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Abstract

Magnetic and neutron diffraction data collected for polycrystalline samples of $PrCu_2Si_2$, $PrCu_2Ge_2$ and $TbCu_2Si_2$ show that the compounds are collinear antiferromagnets. The neutron diffraction data, unlike the magnetic data, do not show any magnetic phase transition in the magnetic ordered state.

Keywords: Rare earth compounds; Ternary intermetallic compounds; Magnetic properties; Magnetic phase transition; Neutron diffraction

1. Introduction

The RCu_2X_2 compounds, where X is Si or Ge, crystallize in tetragonal $ThCr_2Si_2$ ($CeAl_2Ge_2$)-type crystal structures [1]. Magnetic investigations indicate an antiferromagnetic ordering at low temperatures [2]. The magnetic structures determined by the neutron diffraction measurements reveal the AFI magnetic structure for Pr compounds and the AFIV for compounds with R = Tb–Ho [2].

The results of measurements of the temperature dependence of the critical resistance, magnetic susceptibility and heat capacity of $PrCu_2Ge_2$ indicate a discontinuous phase transition at $T = 4.2$ K [3]. The temperature dependence of the heat capacity of $PrCu_2Si_2$ has anomalies at $T_N = 21$ K and at 15 K [4].

We performed new studies of the $PrCu_2Si_2$, $PrCu_2Ge_2$ and $TbCu_2Si_2$ compounds, this time on the E6 diffractometer at the Berlin Neutron Scattering Centre, which offered better incident neutron intensity and permitted us to collect powder data with excellent resolution. In addition, we report the results of a.c. magnetic susceptibility measurements performed in low temperatures.

2. Experimental details and results

Experiments were carried out on polycrystalline samples, as reported in previous papers [5,6]. The a.c. susceptibility was measured using a mutual inductance bridge.

Neutron diffraction patterns were obtained on the E6 diffractometer installed at the BER 2 reactor (Hahn–Meitner Institute, Berlin). The incident neu-

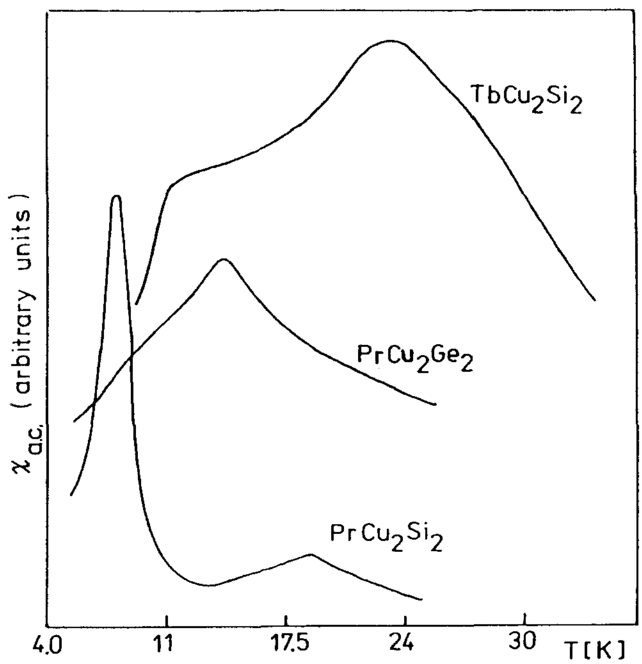

Fig. 1. Temperature dependence of the a.c. susceptibility for $PrCu_2Si_2$, $PrCu_2Ge_2$ and $TbCu_2Si_2$.

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tron wavelength was 2.437 Å. Measurements were made at temperatures from 1.4 to 26.1 K.

The temperature dependence of the a.c. susceptibility (see Fig. 1) shows two anomalies for $PrCu_2Si_2$ (at $T = 8$ and 19 K) and $TbCu_2Si_2$ (at $T = 11$ K and 23 K), and one anomaly for $PrCu_2Ge_2$ at $T = 14$ K.

The neutron diffraction patterns of $PrCu_2Si_2$, $PrCu_2Ge_2$ and $TbCu_2Si_2$ at different temperatures are shown in Figs. 2 and 3. At low temperatures nuclear and magnetic peaks are observed. The intensities of the magnetic peaks in the patterns of $PrCu_2Si_2$ and $PrCu_2Ge_2$ do not change with increasing temperatures. An anomaly at $T = 8$ K for $PrCu_2Si_2$ and 4.2 K for $PrCu_2Ge_2$ is not detected. For $TbCu_2Si_2$ the magnetic peaks disappear at $T_N = 11$ K.

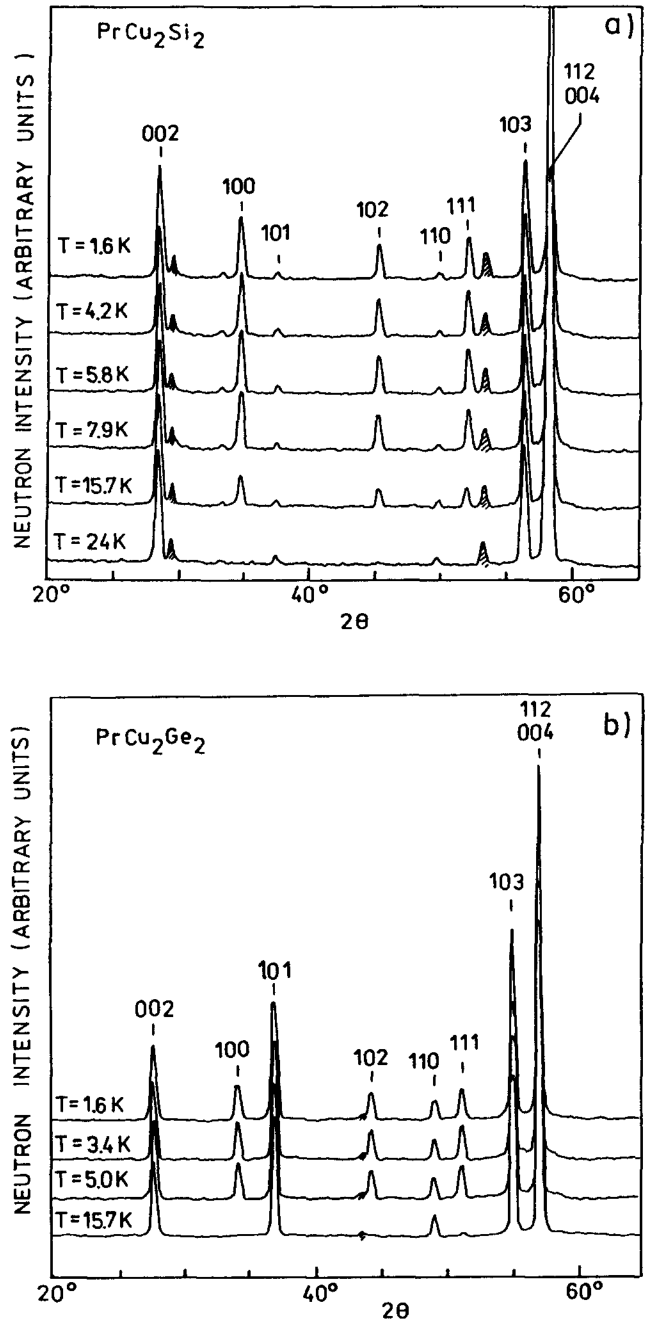

Fig. 2. Neutron diffraction patterns at different temperatures for (a) $PrCu_2Si_2$ and (b) $PrCu_2Ge_2$. Small shaded peaks are due to the impurity phase.

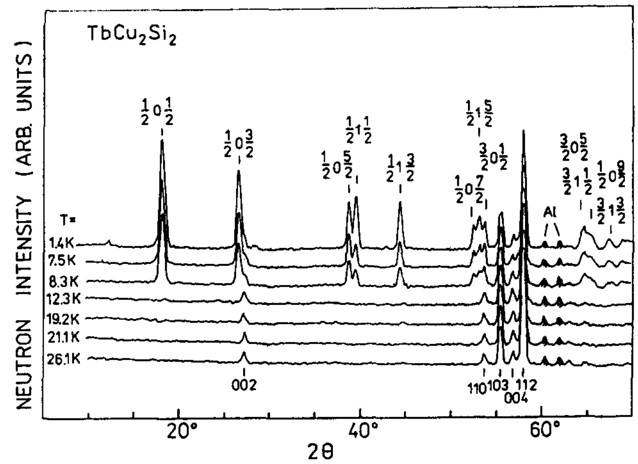

Fig. 3. Neutron diffraction patterns of $TbCu_2Si_2$ at different temperatures.

The neutron intensities were analyzed by the Rietveld profile method using the Full Prof version [7]. The neutron scattering lengths were taken from Ref. [8] and the magnetic form-factors for Pr^{3+} and Tb^{3+} from Ref. [9]. A good agreement between observed and calculated neutron intensities was achieved. The relevant results are summarized in Table 1. These results agree with the previous results [5,6].

3. Discussion

The results presented in this investigation do not reveal additional anomalies in the temperature dependence of the magnetic structure of $PrCu_2Si_2$ and $PrCu_2Ge_2$. In the region between 1.4 K and the Néel temperature a collinear antiferromagnetic structure of the AFI type was detected (see Fig. 4). The $TbCu_2Si_2$ compound has an antiferromagnetic structure of the AFIV type in the region between 1.4 K and $T_N = 11$ K. The ^{141}Pr Mössbauer spectra of $PrCu_2Si_2$ at 4.2 K and

Table 1
Crystal and magnetic data for $PrCu_2Si_2$, $PrCu_2Ge_2$ and $TbCu_2Si_2$

	$PrCu_2Si_2$	$PrCu_2Ge_2$	$TbCu_2Si_2$
T(K)	1.6	1.6	1.4
a (Å)	4.1108(10)	4.1758(9)	3.9820(10)
c (Å)	10.0036(41)	10.2672(27)	9.9820(50)
z	0.3778(10)	0.3801(4)	0.3831(6)
R_N (%)	2.4	4.94	2.6
μ (μ_B)	2.33(5)	2.26(5)	8.47(5)
gJ	3.2	3.2	9.0
R_M (%)	6.0	9.8	5.05

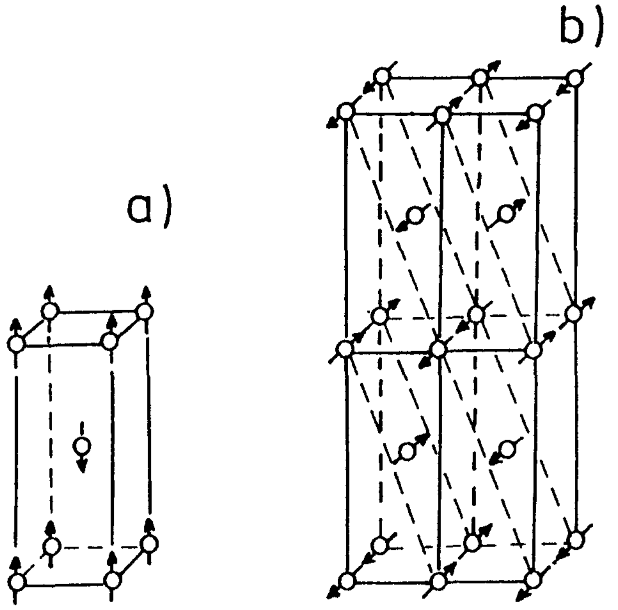

Fig. 4. Magnetic structure of (a) $PrCu_2Si_2$ and $PrCu_2Ge_2$ and (b)$TbCu_2Si_2$.

12 K exhibit a clear hyperfine field splitting. In the temperature range 12–20 K a relaxation process is observed [10]. The anomaly observed at $T = 8$ K in our a.c. susceptibility measurements is probably caused by such a phenomenon. The observed magnetic moment of Pr in both $PrCu_2X_2$ compounds is consistent with the results of the inelastic neutron scattering measurements for $PrCu_2Si_2$ [11], which indicate a magnetic doublet ground state with a reduced magnetic moment ($2.04\mu_B$).

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