MAGNETIC PROPERTIES OF NEW COMPOUNDS RMg_2Cu_9 WITH TWO-DIMENSIONAL ALIGNMENT OF R ATOMS*

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Structural and magnetic properties of new compounds RMg_2Cu_9 were examined. The results indicated that RMg_2Cu_9 crystallize in the $CeNi_3$ type hexagonal structure for R = La, Ce, Pr, Nd, Sm and show magnetic order for R = Ce and Sm, that is in contrast with RMg_2Ni_9 system. Some contrastive physical properties in RMg_2T_9 (T = Ni, Cu) might be originated in both the two-dimensionality of R atoms and the number of carrier.

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1. Introduction

$CeMg_2Ni_9$ crystallizes in the hexagonal $PuNi_3$ type structure, while $CeMg_2Cu_9$ crystallizes in the $CeNi_3$ type structures [1], both of which are built up from the stacking of single layers of CeT_5 (T = Ni, Cu) and double layers of MgT_2 along the c-axis. It have been clarified that $CeMg_2T_9$ system reveal some novel physical properties, for example, no magnetic long range order in RMg_2Ni_9 with R = Ce, Pr, Nd and Gd and almost pressure-independence of T_{N} up to 0.9 GPa for $CeMg_2Cu_9$, that might be reflected two-dimensionality of R atoms [2]. To clarify the influence of two-dimensional arrangement of R atoms, we studied physical properties of light-rare-earth RMg_2Cu_9 (R = La, Pr, Nd and Sm) compounds. In this paper, we report the crystal structure and magnetic properties of new compounds RMg_2Cu_9 (R = La, Ce, Pr, Nd and Sm). Details of the sample preparation and the other experimental procedures are given in Ref. [3].

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2. Results and discussion

2.1. Crystal structure

Figure 1(a) shows powder X-ray diffraction pattern for RMg_2Cu_9 (R = La, Ce, Pr, Nd and Sm) together with the simulation pattern assumed $CeNi_3$ type hexagonal structure. Comparing our experimental pattern with the simulation one, we can conclude that RMg_2Cu_9 (R = La, Ce, Pr, Nd and Sm) is in a single phase of $CeNi_3$ type hexagonal structure. The refined lattice constants are listed in Table I. The lattice constants of RMg_2Cu_9 obey the lanthanide contraction, indicating that R is in a tri-valent state, being in contrast with RMg_2Ni_9 system that Ce is in an intermediate valence state [4].

From the above simulation result, the crystal structure of RMg_2Cu_9 can be drawn in figure 1(b), which is built up of alternating single layers of RCu_5 and double layers of $MgCu_2$ along the c-axis. In this structure, the R-R nearest neighbor distance along the c-axis are almost two-times larger than that in the c-plane (see Table I). Thus, these compounds are characterized by two-dimensional alignment of R atoms.

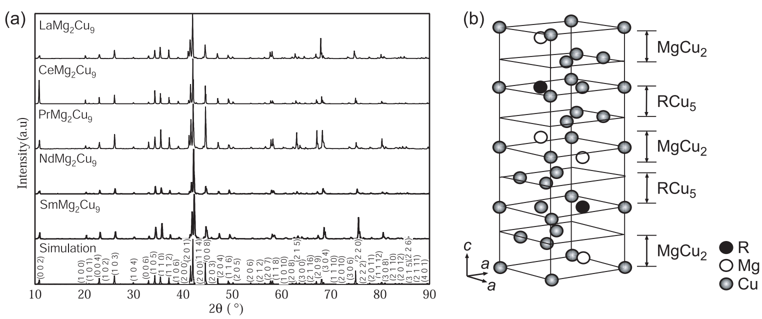

Fig. 1. (a) Powder X-ray diffraction profiles of RMg_2Cu_9 (R = La, Ce, Pr, Nd and Sm) and the simulation pattern assumed $CeNi_3$ type hexagonal structure. (b) The crystal structure of RMg_2Cu_9 with a hexagonal $CeNi_3$ type.

TABLE I

Structural and magnetic properties of RMg_2Cu_9 (R = La, Ce, Pr, Nd and Sm).

RMg_2Cu_9	Lattice constance			R-R nearest neighbor distance		μ_{eff} (μ_B)		θ_p (K)	T_N (K)
	a (Å)	c (Å)	c/a	a (Å)	c (Å)	Obserbed	Theoritical		
$LaMg_2Cu_9$	5.073	16.270	3.207	5.073	8.646				
$CeMg_2Cu_9$	5.061	16.260	3.213	5.061	8.639	2.4	2.54	-15.7	2.7
$PrMg_2Cu_9$	5.052	16.251	3.217	5.052	8.633	3.3	3.58	-21.7	
$NdMg_2Cu_9$	5.041	16.236	3.221	5.041	8.624	3.6	3.62	-1.56	
$SmMg_2Cu_9$	5.027	16.213	3.225	5.027	8.610				10

2.2. Magnetic properties

The magnetization curves for RMg_2Cu_9 at 2 K are shown in figure 2. For $LaMg_2Cu_9$, the magnetization decrease linearly with increasing magnetic field, indicating $LaMg_2Cu_9$ is diamagnetism. On the other hand, the magnetization for R = Ce, Pr and Sm, linearly increase with increasing magnetic field, indicating that these compounds are antiferromagnetism or paramagnetism. For $NdMg_2Cu_9$ on the contrary, the magnetization gradually increases with increasing magnetic field.

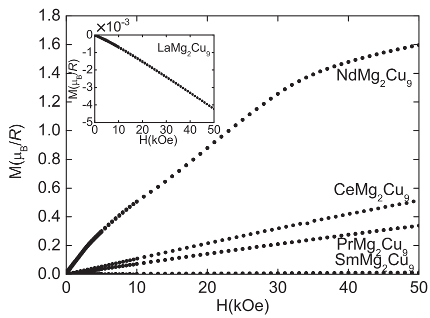

Fig. 2. Magnetization curve for RMg_2Cu_9 at 2 K. The inset shows the magnetization curve for $LaMg_2Cu_9$.

Figure 3 shows the temperature dependence of the magnetic susceptibility χ for RMg_2Cu_9 with (a) R = Ce, Pr and Nd, (b) La, and Sm. The χ of

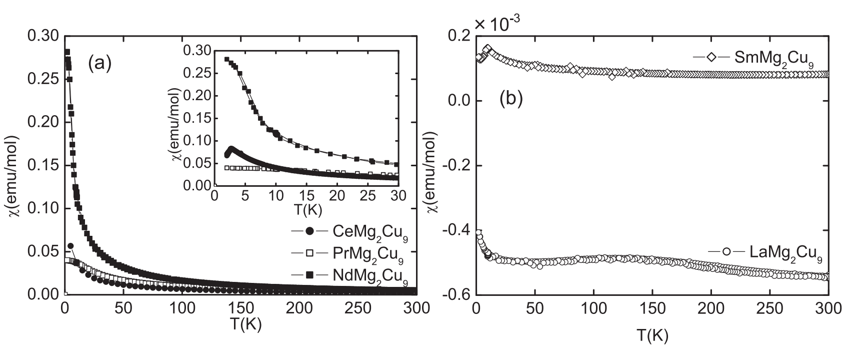

Fig. 3. Temperature dependence of the magnetic susceptibility at 10 kOe for RMg_2Cu_9 (a) R = Ce, Pr, Nd and (b) La, Sm.

$LaMg_2Cu_9$ and $SmMg_2Cu_9$ are almost independent of temperature, reflecting diamagnetism and Van Vleck paramagnetism. The χ of $CeMg_2Cu_9$ and $SmMg_2Cu_9$ exhibit a small peak at 2.7 K and 10 K respectively, suggesting the existence of antiferromagnetic order below these temperatures. On the other hand, the χ of $PrMg_2Cu_9$ was observed no magnetic anomaly at 2 K, which is due to singlet ground state caused by a crystal electric field splitting. The χ for $NdMg_2Cu_9$ shows induced-ferromagnetic behavior below about 4 K. The $1/\chi$ for R = Ce, Pr, Nd follows the Curie–Weiss Law with effective magnetic moments that are close to theoretical values expected for the R^{3+} free ion. The effective magnetic moment μ_{eff}, Curie–Weiss temperature θ_p and magnetic ordering temperature are summarized in Table I. Since the θ_p for $NdMg_2Cu_9$ is near 0 K, it seems likely that the ground state of $NdMg_2Cu_9$ is in a paramagnetic state and shows induced-ferromagnetism in high field at $T < 4$ K.

It should be noted that RMg_2Cu_9 for R = Ce and Sm show antiferromagnetic order at low temperature, while RMg_2Ni_9 show no-magnetic order even for Gd-system with large spin components. The reason of no magnetic order for RMg_2Ni_9 was originally thought to be the two-dimensionality of rare earth arrangement [3]. However, there is antiferromagnetic order in the RMg_2Cu_9 with R = Ce and Sm, although nearest neighbor R–R distances along c-axis are larger than that in the RMg_2Ni_9. Therefore, it seems likely that the reason of no magnetic order for RMg_2Ni_9 is not only in a two-dimensionality of R atoms, but also in a low carrier number of conduction electrons which could be observed as a high electrical resistivity compared to that in the Cu system [2].

3. Summary

We have clarified that new compounds of RMg_2Cu_9 crystallize in the hexagonal $CeNi_3$ type structure for R = La, Ce, Pr, Nd, Sm and show magnetic order for R = Ce and Sm, that is in contrast with the RMg_2Ni_9 system. The physical properties of RMg_2T_9 for T = Ni, Cu therefore might be originated in both the two-dimensionality of R atoms and the number of carrier.

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