ВІСНИК ЛЬВІВ. УН-ТУ *VISNYK LVIV UNIV.*
Серія фізична. 2007. Вип.40. С.268-279 *Ser.Physic. 2007. N40. P.268-279*

PACS number(s): 71.70.Ch

CRYSTAL ELECTRIC FIELD EFFECT IN RT_xX_2 COMPOUNDS

A. Gil

Faculty of Mathematical and Natural Sciences, JD University,
Al. Armii Krajowej 13/15, 42-200 Czestochowa, Poland

The RT_xX_2 type metallic compounds where R is a rare-earth element, T is a d-electron element and X is a p-electron element (X = Si, Ge, Sn) crystallize in the orthorhombic crystal structure of the $CeNiSi_2$ type.

The systems discussed exhibit complex magnetic behaviour. Their magnetism arises from the long range interaction of the magnetic moments localized on the rare-earth ions, probably those described by RKKY model. The magnetic ordering in these systems is not purely of the RKKY-type but is modified by the crystalline electric field effect, which can significantly influence the magnitude of the Néel temperature. The CEF effects are also responsible for the observed decrease in the rare-earth magnetic moments as compared with the free ion values.

The determination of the CEF parameters is important for understanding the nature of magnetic properties of intermetallic compounds. The B_n^m parameters were calculated for RTX_2 compounds using the so-called point-charge model. The quadrupole splitting observed in the Mössbauer spectra of GdT_xSn_2 compounds (T=Fe, Co, Ni, Cu) allow to determined the experimental values of B_2^0 parameters for RTX_2 compounds.

Key words: crystal field, magnetic properties.

During the last few years the RT_xX_2 ($x \leq 1$) type intermetallic compounds (R is a rare-earth, T is a d-electron metal and X is a p-electron metalloid (X = Si, Ge, Sn)) have been a subject of intensive studies because of their intriguing physical properties, which have both fundamental and practical significance.

The RT_xX_2 compounds crystallize in different orthorhombic crystal structures [1]:

- $CeNiSi_2$–type (space group Cmcm);
- $TbFeSi_2$–type, which is very similar to the $CeNiSi_2$, but R, T and Si atoms are located in alternating layers;
- $YIrGe_2$–type (space group Immm);
- $LuNiSn_2$–type (space group Pnma);
- $TiMnSi_2$ or $ZrCrSi_2$–type (space group Pbam);
- $NdRuSi_2$–monoclinic type, which is described as a distorted variant of the $CeNiSi_2$–type (space group $P2_1/m$).

All silicides crystallize in the stoichiometric structure (x=1), while germanides and stannides form mainly defected structures RT_xX_2 (x<1) with defects in d-electron metal sublattice.

Majority of these compounds crystallize in the orthorhombic $CeNiSi_2$–type structure [2] (Fig. 1) and discussion in this work concerns compounds with this structure type.

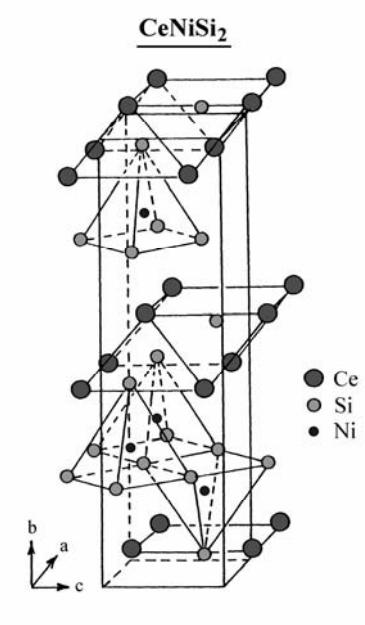

Fig. 1. Crystal structure of $CeNiSi_2$–type

Magnetic measurements indicate that majority of compounds order antiferromagnetically at low temperatures. Above the Néel temperatures, the effective magnetic moments are close to the free R^{3+} ion values ($g\sqrt{J(J+1)}$). Only for compounds with T = Mn, a localized magnetic moment on Mn has been observed (Fig. 2).

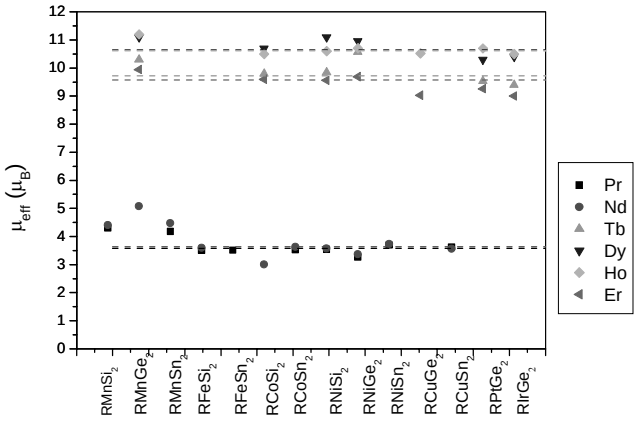

Fig. 2. Effective magnetic moments for RT_xX_2 compounds

The crystal structure has a distinct layer character. Rare-earth atoms occupy the layers perpendicular to the b-axis, and they are separated by layers of other atoms. In majority of compounds, the magnetic moments located in the same planes are coupled ferromagnetically, while the coupling between two moments in adjacent planes is antiferromagnetic.

Magnetic data for the RT_xX_2 ternary compounds are summarized in Table 1.

Table 1

Magnetic properties of RT_xX_2 compounds

Compound	TMO[1]	θ_p [K]	μ_{eff} [μ_B]	$T_{C,N}$ [K]	μ_R [μ_B]	MMD[2]	Ref.
$CeMnSi_2$	F	420	3,52	398	0,23	|| *b*	3,4
$PrMnSi_2$	F	450	4,29	434,34	2,04	|| *b*	3,4
$NdMnSi_2$	F	460	4,41	441,40	1,8	|| *c*	3,4
$SmMnSi_2$	F	482	3,02	464	1,74		3
$NdMn_{0,42}Ge_2$	AF	-23,5	5,08	34	1,55	|| *c*	5
$SmMn_{0,4}Ge_2$		-57,2	3,7				5
$GdMn_{0,38}Ge_2$	AF	-30,5	8,75	35			5
$TbMn_{0,33}Ge_2$	AF	-37,1	10,3	26	7,0	|| *c*	5
$DyMn_{0,32}Ge_2$	AF	-17,8	11,1	30			5
$HoMn_{0,33}Ge_2$	AF	-12,8	11,2	7	7,3	|| *c*	5
$ErMn_{0,27}Ge_2$	AF	-10,7	9,95	3,4			5
$CeMnSn_2$	F	117	4,03	320	0,4		6
$CeMn_{0,5}Sn_{1,83}$	F	369	3,8	520	0,55		6
$PrMn_{0,5}Sn_{1,83}$	AF	-14	4,18	16	3,09	|| *c*	7

$NdMn_{0,5}Sn_{1,83}$	AF	-39	4,48	20			6
$SmMn_{0,29}Sn_{1,56}$	AF	-105	1,97	35			6
$PrFeSi_2$	F	44	3,5	26	2,58	II *b*	3, 8
$NdFeSi_2$	AF	41	3,6	6	3,17	II *b*	3, 8
$CeFe_{0,63}Ge_2$	NM Kondo	-115	2,8				9
$CeCoSi_2$	PP	-240	1,6				10
$NdCoSi_2$	AF	-28	3,0	2,15	2,18		11, 12
$SmCoSi_2$	AF			4			11
$GdCoSi_2$	AF	-8	7,5	7,5			11
$TbCoSi_2$	AF	-18	9,8	16	9,16	II *a*	11, 13
$DyCoSi_2$	AF	8	10,7	10	5,74	(*a*-*c*)	11, 14
$HoCoSi_2$	AF	-6	10,5	6,3	6,72	II *a*	11, 14
$ErCoSi_2$	AF	-17	9,6	2,6	4,63	(*a*-*c*)	11, 15
$CeCo_{0,89}Ge_2$	AF Kondo	-90	2,55	3			9
$CeCo_{0,48}Sn_2$		-9	2,71				16
$PrCo_{0,33}Sn_2$		-2	3,52				16
$NdCo_{0,33}Sn_2$		-7	3,63				16
$GdCo_{0,27}Sn_2$	AF			16,5			17
$TbCo_{0,25}Sn_2$	AF			18,8	7,14	(*a*-*c*)	17
$DyCo_{0,26}Sn_2$	AF			7			17
$HoCo_{0,23}Sn_2$	AF			5,6	6,79	(*a*-*c*)	17
$ErCo_{0,24}Sn_2$	AF			4,7	6,15	(*a*-*c*)	18
$CeNiSi_2$	MV	-150	2,6				19
$PrNiSi_2$	F	20	3,54	20	3,09	II *c*	20
$NdNiSi_2$	F	8	3,57	9,5	2,38	II *c*	20
$SmNiSi_2$	AF		0,88	9,8			21
$GdNiSi_2$	AF	-33	9,4	19,3	5,8		21
$TbNiSi_2$	AF	-17 -5	9,84 10,1	37,6 36,2	8,7	II *c*	21 22
$DyNiSi_2$	AF	-12 21	11,1 10,6	25 24	7,5	II *c*	21 23

$HoNiSi_2$	AF	3 3	10,6 11,05	10 10	8,13	ll *c*	21 24
$ErNiSi_2$	AF	4 20	9,56 10,11	3,1 3,4	7,6	ll *b*	21 25
$CeNiGe_2$	AF HF	-20,8	2,51	3,9, 3,2			19
$PrNiGe_2$	F	13,8	3,26	15			21
$NdNiGe_2$	F	7 6	3,31 3,37	15 6	2,32	ll *c*	21 26
$SmNiGe_2$		-13,6	0,97				21
$GdNiGe_2$	AF	-33	8,6	24,5			21
$TbNiGe_2$	AF	-31,5	10,57	42	8,8	ll *c*	21, 27
$TbNi_{0,4}Ge_2$	AF			16	5,6	ll *c*	28
$TbNi_{0,6}Ge_2$	AF			31	8,9	ll *c*	28
$TbNi_{0,8}Ge_2$	AF			38	8,7	ll *c*	28
$DyNiGe_2$	AF	-12	10,96	22			21
$HoNiGe_2$	AF	-5	10,71	7,6			21
$HoNi_{0,64}Ge_2$	AF			11	6,7	ll *c*	27
$ErNiGe_2$	AF	-2	9,69	2,5			21
$ErNi_{0,65}Ge_2$	AF			2,5	2,8	ll *a*	
$CeNiSn_2$	AF	-6,9	2,56	4			19
$CeNi_{0,84}Sn_2$	AF			4, 3	2,0	ll *c*	29
$PrNiSn_2$		-2	3,69				16
$NdNiSn_2$		-3	3,73				16
$GdNi_{0,4}Sn_2$	AF			27			30
$TbNi_{0,26}Sn_2$	AF			17,4	8,05	(*a*-*c*)	31
$DyNi_{0,22}Sn_2$	AF			8	9,2	(*b*-*c*)	32
$HoNi_{0,16}Sn_2$	AF			6,6	7,46	(*a*-*c*)	31
$ErNi_{0,15}Sn_2$	AF			4	9,16	ll *a*	18
$CeCu_{0,86}Ge_2$	AF	7		15,6 16,5	1,85	ll *c*	19 33
$PrCu_{0,76}Ge_2$	F			23			34
$TbCu_{0,4}Ge_2$	AF	-25	10,4	39	8,82	ll *c*	35
$HoCu_{0,33}Ge_2$	AF	-8,0	10,52	8	8,18	ll *c*	36
$ErCu_{0,25}Ge_2$	AF	4,1	9,03	4,5	7,89	ll *a*	36
$CeCu_{0,62}Sn_{1,83}$		1	2,4				16
$PrCu_{0,62}Sn_{1,83}$		10	3,62				16
$NdCu_{0,74}Sn_{1,96}$		-6	3,8				16

[1] TMO –type of magnetic ordering, [2] MMD –magnetic moment direction

In all series of compounds, the R^{3+}–R^{3+} distances are large (about 4 Å), suggesting that direct magnetic interactions are highly improbable. The stability of the observed magnetic ordering schemes may be considered as being due to interactions via conduction electrons described by the RKKY model [37–39].

In this mechanism, the ordering temperature should be proportional to the de Gennes factor [40]: $G = (g_J - 1)^2 J(J+1)$, where g_J is the Landé factor and J — the total angular momentum of the rare-earth ion, and the highest ordering temperature should be found in the Gd-containing compounds. Contrary to the latter expectation, in majority of our systems, the $T_N(G)$ dependence is peaked aroud the value of G corresponding to terbium. (Fig. 3). The $T_{C,N}$ shifting may result from the crystalline electric field effect CEF. This is why the CEF terms should be added to the exchange Hamiltonian. The rare earth ions are in the *4(c)* site of the low symmetry *mm*. Neither experimental nor calculated data concerning CEF parameters for RT_xX_2 are available.

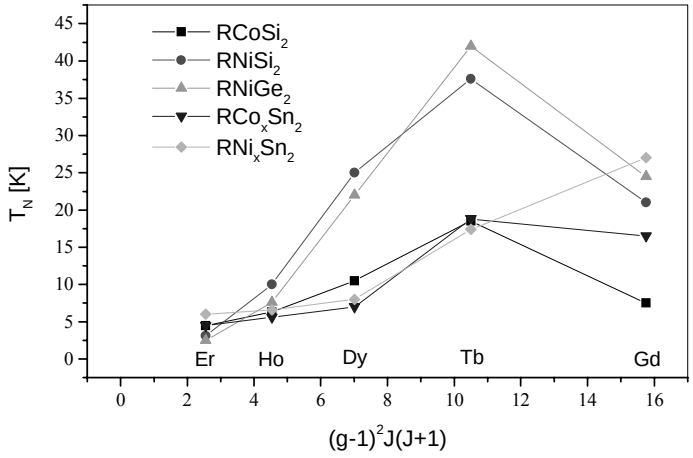

Fig. 3. Observed Néel temperatures in some RT_xX_2 intermetallics vs de Gennes function

The interaction of the CEF with the moments of rare-earth atom electrons is given by the Hamiltonian [41]:

$$H_{CF} = \sum_{n=0}^{n'} \sum_{m=-n}^{+n} B_n^m O_n^m (J),$$

where *n'* takes a maximum value of *n* appropriate to the rare-earth atom considered, B_n^m are the crystal field intensity parameters and $O_n^m(J)$ represent polynomials of the angular momentum operators J_+, J_-, J_z and J^2.

The rare-earth site in the RTX_2 compounds has the point symmetry *mm*. In such symmetry the CEF Hamiltonian can be written as follows:

$$H_{CF} = B_2^0 O_2^0 + B_2^2 O_2^2 + B_4^0 O_4^0 + B_4^2 O_4^2 + B_6^0 O_6^0 + B_6^2 O_6^2 + B_6^4 O_6^4 + B_6^6 O_6^6.$$

When B_2^0 is the leading term in the crystal field Hamiltonian, then its sign gives information about the single ion magnetic anisotropy. For a positive value of the B_2^0 parameter the basal plane ($\perp z$) is preferred for the magnetic moment direction while for a negative value an ordering along *z*-axis is anticipated [42].

The neutron diffraction data collected in Table 1 indicate that the rare-earth magnetic moments in RTX_2 compounds prefer the orientation in the basal plane (010). In majority of RTX_2 compounds with R = Pr, Nd, Tb, Ho, the rare-earth moments are parallel to the *c*-axis and for R = Er the magnetic moment is parallel to the *a*-axis.

The B_n^m parameters were determined for RTX_2 compounds using the so-called point-charge model [43] taking *b*-axis as z-axis and *c, a*-axes as *x*, *y*-axes respectively. In this approximation the electrostatic potentials of the most important neighbours are summed. The parameters B_n^m can be written as:

$$B_n^m = \langle \theta_n \rangle \langle r^n \rangle K_n^m A_n^m .$$

Values for $\langle \theta_n \rangle \langle r^n \rangle$ have been collected by Franse and Radwański [44]. The coefficients A_n^m are known as the CEF coefficients.

The computations were made for the nearest neighbours (see Fig. 4). The B_2^0, B_2^2 and B_4^0 parameters are given by the formulas:

$$B_2^0 = -\alpha_J \langle r^2 \rangle \frac{\pi e^2}{20} \sum_i \frac{Z_i}{R_i^3} \left(3\cos^2\theta - 1\right);$$

$$B_2^2 = -\alpha_J \langle r^2 \rangle \frac{\pi e^2}{10} \sum_i \frac{Z_i}{R_i^3} \sin^2\theta \left(2\cos^2\varphi - 1\right);$$

$$B_4^0 = -\beta_J \langle r^4 \rangle \frac{4\pi e^2}{9} \sum_i \frac{Z_i}{R_i^5} \left(35\cos^4\theta - 30\cos^2\theta + 3\right)\ldots .$$

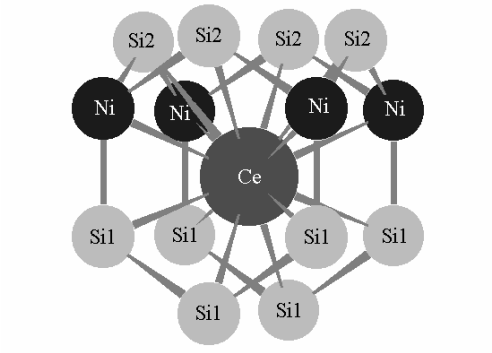

Fig. 4. The nearest neighbours of a rare atom in the RTX_2 compounds

The results of calculations of B_n^m are shown in Table 2 (the sixth-order parameters were omitted because they are very small). The calculations suggest that the preferred direction of magnetic moment occurs in the plane (010) as well as that the B_2^0 and B_2^2 and B_4^0 parameter play an important role in the CEF Hamiltonian.

Table 2

Crystalline electric field parameters for $RNiSi_2$ compounds calculated using the so-called point-charge model

R	B_2^0 [meV]	B_2^2 [meV]	B_4^0 [meV]	B_4^2 [meV]	B_4^4 [meV]
Ce	2,741	9,445	6,979	-0,229	-0,257
Pr	0,907	3,126	-0,656	0,022	0,024
Nd	0,256	0,882	-0,222	0,007	0,008
Tb	0,307	1,058	0,055	-0,002	-0,002
Dy	0,184	0,634	-0,025	0,001	0,001
Ho	0,061	0,209	-0,012	0,0004	0,0004
Er	-0,067	-0,231	0,014	-0,0005	-0,0005

In the most of studied compounds with the $CeNiSi_2$ – type crystal structure the orientation of magnetic moments agree with the positive sign of the B_2^0 parameter (along the *c*-axis) but for the compounds with Er the negative sign of B_2^0 parameter suggests the *b*-axis as the preferable direction.

It has been also found that a decrease in the number of defects in the Ni sublattice leads to an increase of the B_2^0 parameter and to a reduction of the B_2^2 parameter (see Table 3).

Table 3

Influence of Ni sublattice defects in $CeNi_xSi_2$ on the CEF parameters

	B_2^0 [meV]	B_2^2 [meV]	B_4^0 [meV]	B_4^2 [meV]	B_4^4 [meV]
$CeNiSi_2$	2,741	9,445	6,979	-0,229	-0,257
$CeNi_{0,75}Si_2$	4,339	9,296	6,875	-0,229	-0,244
$CeNi_{0,5}Si_2$	5,936	9,147	6,771	-0,230	-0,232
$CeNi_{0,25}Si_2$	7,533	8,998	6,667	-0,230	-0,220
$CeSi_2$	9,130	8,849	6,563	-0,230	-0,208

The samples of gadolinium stannides GdT_xSn_2 (T = Fe, Co, Ni and Cu) have been studied by ^{119}Sn and ^{155}Gd Mössbauer spectroscopy [45].

Since the trivalent gadolinium ions are in the ground electronic states with spherical distribution of *4f* electronic charge, only the lattice term contributes to the magnitude of V_{zz} in the rare earth site. Hence, the determination of the sign and magnitude of $\Delta E_Q = eV_{zz}Q$ at the Gd site together with the asymmetry parameter η allow

to estimate the quadrupolar terms B_2^0 and B_2^2 in Stevens expansion of the crystal field Hamiltonian, as they are related by two simple formulas:

$$B_2^0[K] = -\alpha_J \cdot \left\langle r^2 \right\rangle_{4f} \cdot 90,2 \cdot \Delta E_Q \left({}^{155}Gd \right), \quad B_2^2 = \eta B_2^0.$$

Here, α_J is the appropriate Stevens factor, the mean squared radius of the *4f* wave function $\left\langle r^2 \right\rangle_{4f}$ is expressed in atomic units and ΔE_Q in mm/s.

Görlich et al. [45] determined ΔE_Q = -0,32 mm/s for $GdNi_{0.32}Sn_2$ compound and I tried to determine the B_2^0 parameters for RNi_xSn_2 compounds which are shown in Table 4.

Table 4

B_2^0 parameters for RNi_xSn_2 compounds

R	Ce	Pr	Nd	Tb	Dy	Ho	Er
B_2^0 [meV]	-0,640	-0,219	-0,061	-0,071	-0,043	-0,014	0,016

These results indicate that the change of the X element from Si to Sn may leads to a change in the direction of the magnetic moments. Another reason for a change of B_2^0 signs maybe a non stoichiometry of stannides.

The discussed compounds crystallize in the orthorhombic crystal structures of the $CeNiSi_2$ type. The silicides form stoichiometric compounds while germanides and stannides show mainly non stoichiometric structures.

It is well established now that in these compounds (except those with T=Mn) the magnetic moment is localized only on the rare-earth atoms. Their magnetism arises from the interaction of the magnetic moments localized on the rare-earth ions.

The large interatomic R-R distances (about 4 Å) and the appearance of complex magnetic structures suggest that long-range magnetic ordering, realized probably by conduction electrons (RKKY model) play a dominant role in forming the magnetic ordering.

The Néel and Curie temperatures determined for presented families only in part follow the de Gennes scaling. This effect suggests that the main interaction is not purely of the RKKY-type but is modified by the crystalline electric field effect, which generally can enhance or even decrease the magnitude of the Néel temperature and is also responsible for the observed decrease in the rare-earth magnetic moments as compared with the free ion values.

The calculations of CEF parameters suggest that the preferred direction of magnetic moment occurs in the plane (010) as well as that the B_2^0 and B_2^2 and B_4^0 parameter play an important role in the CEF Hamiltonian. In the most of studied compounds the orientations of magnetic moments agree with the positive sign of the B_2^0 parameter (along the *c*-axis).

1. *Parthé E., Chabot B.* Handbook on the Physics and Chemistry of Rare Earth, eds. K. A. Gschneidner Jr and L. Eyring; Elsevier Science Publ. B. Vol. Chap. 48. 1984. 113 p.
2. *Bodak O. I., Gladyshevsky E. I.* Sov. Phys. Cryst. 1970. Vol. 14. 859 p.
3. *Venturini G., Malaman B., Meot-Meyer M.* et al. Revue de Chimie Minerale. 1986. Vol. 23. 162 p.
4. Malaman B., Venturini G., Pontonnier L., Fruchart D. J. Magn. Magn. Mater. 1990. Vol. 86. 349 p.
5. *Gil A., Leciejewicz J., Małetka K., Szytuła A.* et al. J. Magn. Magn. Mater. 1994. Vol. 129. L. 155.
6. *Weitzer F., Hiebel K., Rogl P.* Solid State Commun. 1992. Vol. 82. 353 p.
7. *Gil A., Oleś A., Sikora W., Szytuła A.* J. Alloys Comp. 2003. Vol. 360. 21 p.
8. *Malaman B., Venturini G., LeCaër G., Pontonnier L.* et al. Phys. Rev. B41. 1990. 4 700 p.
9. *Das I., Sampathkumaran E. V.* Solid State Commun. 1992. Vol. 83. 765 p.
10. *Bodak O. I., Gladyshevsky E. I., Levin E. M., Lutsiv R. V.* Dopov. Akad. Nauk Ukr. RSR. Ser. A12. 1977. 1129 p.
11. *Pellizione M., Braun H. F., Muller J.* J. Magn. Magn. Mater.; 1982. Vol. 30. 33 p.
12. *André G., Oleś A., Szytuła A.* Phys. Stat. Solidi. 1989. Vol. 116. K. 29.
13. *Penc B., Szytuła A., Wawrzyńska E., Hernandez-Velasco J.* J. Alloys Comp. 2004. Vol. 366. 120 p.
14. *Szytuła A., Ptasiewicz-Bąk H., Leciejewicz J., Bażela W.* J. Magn. Magn. Mater. 1989. Vol. 80. 189 p.
15. *André G., Bourée F., Oleś A., Sikora W.* et al. J. Magn. Magn. Mater. 1993. Vol. 124. 69 p.
16. *Skolozdra R. V.* Handbook on the Physics and Chemistry of Rare Earths. eds. K. A. Gschneidner and L. Eyring. 1997. Vol. 24. 399 p.
17. *Gil A., Penc B., Wawrzyńska E., Hernandez-Velasco J., Szytuła A., Zygmunt A.* J. Alloys Comp. 2004. Vol. 365. 31 p.
18. *Penc A, Wawrzyńska E., Szytuła A., Gil A., Hernandez-Velasco J., Zygmunt A.* J. Alloys Comp. 2004. Vol. 375. L1.
19. *Pellizione M., Braun H. F., Muller J.* J. Magn. Magn. Mater. 1982. Vol. 30. 33 p.
20. *Schobinger-Papamantellos P., Buschow K. H. J.* J. Alloys Comp. 1992. Vol. 18. 551 p.
21. *Gil A., Szytuła A., Tomkowicz Z., Wojciechowski K.* et al. J. Magn. Magn. Mater. 1994. Vol. 129. 271 p.
22. Schobinger-Papamantellos P., Buschow K. H. J. J. Less-Common Met. 1991. Vol. 171. 321 p.
23. *Schobinger-Papamantellos P., Ritter C., Buschow K. H. J.* J. Alloys Comp. 1998. Vol. 264. 89 p.
24. *Schobinger-Papamantellos P., Fauth F., Buschow K. H. J.* J. Alloys Comp. 1997. Vol. 252. 50 p.
25. *Schobinger-Papamantellos P., Buschow K. H. J.* et al. J. Magn. Magn. Mater. 1998. Vol. 189214.
26. *Schobinger-Papamentellos P., Krimmel A., Grauel A., Buschow K. H. J.* J. Magn. Magn. Mater. 1993. Vol. 125. 151 p.
27. *Bażela W., Leciejewicz J., Małetka K., Szytuła A.* J. Magn. Magn. Mater. 1992. Vol. 109. 305 p.

28. *Schobinger-Papamentellos P., Buschow K. H. J., Ritter C.* J. Alloys Comp. 1999. Vol. 287. 51 p
29. *Schobinger–Papamantellos P., Rodriguez-Carvajal J., Buschow K.H.J.* J. Alloys Comp. 1996. Vol. 240. 85 p.
30. *Gil A., Penc B., Baran S., Hernandez-Velasco J., Szytuła A., Zygmunt A.* J. Alloys Comp. 2003. Vopl. 361. 32 p.
31. *Gil A., Penc B., Baran S., Wawrzyńska E., Szytuła A.* et al. Neutron Scattering and Complementary Methods in Investigations of Condensed Phase, Vol. 1, University of Podlasie Publishing House. 2003. Monograph. N 45, 103 p.
32. *Gil A., Penc B., Hernandez-Velasco J., Szytula A., Zygmunt A.* Physica B. 2004. Vol. 350. e119.
33. *Gil A., Penc B., Gondek Ł., Szytuła A., Hernandez-Velasco J.* J. Alloys Comp. 2002. Vol. 346. 43 p.
34. *Rawat R., Das I.* Phys. Rev. 2001. Vol. B64.
35. *Schobinger-Papamentellos P., Buschow K.H.J.* J. Alloys Comp. 1992. Vol. 187. 73 p.
36. *Gil.A., Kaczorowski D., Hernandez-Velasco J., Penc B.* J. Alloys Comp. 2004. Vol. 384. L4.
37. *Ruderman M. A., Kittel C.* Phys. Rev. 1954. Vol. 96. 99 p.
38. *Kasuya T.* Prog. Theor. Phys. (Kyoto); 1956. Vol. 16. 45 p.
39. *Yoshida K.* Phys. Rev. 1957. Vol. 106. 893 p.
40. *Gennes de P. G.* J. Phys. Radium: 23. 1962. Vol. 510. 630 p.
41. *Stevens K. W. H.* Proc. Phys. Soc. Londyn. A65. 1952. 209 p.
42. *Wallace W.E., Sankar S.G., Rao V.U.S.* Crystal field effects in rare-earth intermetallic compounds, in: Structure and Bonding. Berlin.Vol. 33. 1997.
43. *Hutchings M.T.* Solid State Physics. Vol.16. F. Seits, D. Turnbull Eds.; Academic Press, New York. 1964. 227 p.
44. *Franse J.J. M. anRadwanski d R.J.* Handbook of Magnetic Materials. Vol. 7. Ed. K. H. J. Buschow. 1993. 307 p.
45. *Görlich E.A., Łątka K., Kmieć R., Tomkowicz Z., Warkocki W.* Molecular Physics Reports. 2000. Vol. 30. 59 p.

ЕФЕКТ КРИСТАЛІЧНОГО ПОЛЯ В СПОЛУКАХ ТИПУ RT_xX_2

А. Гіл

Факультет математики і природничих наук, університет імені Яна Длугоша
вул. Армії Крайовей 13/15, 42-200 Ченстохова, Республіка Польща

У статті досліджено сполуки RT_xX_2 (R – рідкоземельні елементи, T – елементи з валентними *d*-електронами, X – елементи з *p*-електронами), що мають ромбічну структуру типу $CeNiS_2$.

Розраховані параметри B_n^m для RTX_2 сполук у разі використання моделі точкового заряду. Простежено в Месбауерівських спектрах GdT_xSn_2 (T = Fe, Co, Ni, Cu) квадрупольне розщеплення дало змогу з'ясувати величину параметра B_2^0 для сполук RTX_2.

Ключові слова: кристалічне поле, магнітні властивості.

Стаття надійшла до редколегії 29.05.2006
Прийнята до друку 26.02.2007