

Table of contents

VIII/11 Nanocrystalline Materials Subvolume A

	List of frequently used symbols and abbreviations	XI
	Symbols	XI
	Abbreviations	XIV
	Nanostructured hard magnetic intermetallic alloys – General introduction	1
1	Rare earth–transition metal alloys: Co–Sm, Nd–Fe–B, Fe–Sm, and bulk amorphous	3
	References	5
1.1	Hard magnetic R–Co nanomaterials	6
	References	7
1.1.1	RCO_3 type	8
1.1.1.1	Single-phase RCO_3	8
1.1.1.1.1	Crystal structure and lattice parameters	8
1.1.1.1.2	Magnetic properties	8
	References	12
1.1.1.2	RCO_3 -based nanocomposites	13
1.1.1.2.1	Crystal structure and lattice parameters	13
1.1.1.2.2	Magnetic properties	13
	References	15
1.1.2	R_2Co_7 type	16
1.1.2.1	Single-phase R_2Co_7	16
1.1.2.1.1	Crystal structure and lattice parameters	16
1.1.2.1.2	Magnetic properties	16
	References	20
1.1.2.2	R_2Co_7 -based nanocomposites	21
1.1.2.2.1	Crystal structure and lattice parameters	21
1.1.2.2.2	Magnetic properties	22
	References	26
1.1.3	$\text{R}_{1-s}\text{Co}_{5+2s}$ type	27
	References	28
1.1.3.1	RCO_5 ($s = 0$)	29
1.1.3.1.1	Single-phase-based RCO_5 ($s = 0$)	29
1.1.3.1.1.1	Crystal structure and lattice parameters	29
1.1.3.1.1.2	Magnetic properties	32
1.1.3.1.1.3	Corrosion properties	43
1.1.3.1.2	RCO_5 -based nanocomposites	44
1.1.3.1.2.1	Crystal structure and lattice parameters	44
1.1.3.1.2.2	Magnetic properties	47
1.1.3.1.2.3	Nuclear gamma resonance (NGR) data	62
1.1.3.1.2.4	Electrical properties	62
	References	64
1.1.3.2	$\text{RCO}_{(s+C)}\text{-RCO}_7$ type ($0 < s \leq 0.22$)	68
1.1.3.2.1	Single-phase-based $\text{RCO}_{(s+C)}\text{-RCO}_7$	68
1.1.3.2.1.1	Crystal structure and lattice parameters	68

1.1.3.2.1.2	Magnetic properties	70
1.1.3.2.1.3	Corrosion resistance	75
1.1.3.2.2	RCo _(5+C) -RCo ₇ -based nanocomposites	75
1.1.3.2.2.1	Crystal structure and lattice parameters	75
1.1.3.2.2.2	Magnetic properties	76
	References	80
1.1.3.3	R ₂ Co ₁₇ type (<i>s</i> = 0.33)	82
1.1.3.3.1	Single-phase R ₂ Co ₁₇ -based alloys	82
1.1.3.3.1.1	Crystal structure, lattice parameters, nanostructure	82
1.1.3.3.1.2	Magnetic properties	85
1.1.3.3.2	R ₂ Co ₁₇ -based nanocomposites	89
1.1.3.3.2.1	Crystal structure and lattice parameters	89
1.1.3.3.2.2	Magnetic properties	90
	References	96
1.1.3.4	Z-Nanocomposites	97
1.1.3.4.1	Crystal structure, lattice parameters, nanostructure	97
1.1.3.4.2	Magnetic properties	101
1.1.3.4.3	Electrical properties	115
1.1.3.4.4	Nuclear gamma resonance (NGR) data	115
1.1.3.4.5	Corrosion properties	115
	References	116
1.2	(R,R') ₂ (Fe,M) ₁₄ X materials	118
	References	119
1.2.1	(R,R') ₂ (Fe,M) ₁₄ B type	120
	References	121
1.2.1.1	Stoichiometric (R,R') ₂ (Fe,M) ₁₄ B or (R,R') _{11.7} (Fe,M) _{82.3} B ₆ (R,R'/Fe,M = 11.7/83.3 = 0.14)	122
1.2.1.1.1	Crystal structure and lattice parameters	122
1.2.1.1.2	Magnetic properties	123
1.2.1.1.3	Nuclear gamma resonance (NGR) data	134
	References	135
1.2.1.2	(R,R') ₂ (Fe,M) ₁₄ B-based nanocomposites	136
1.2.1.2.1	R,R'-rich (Fe,M)-B-based nanocomposites (R,R'/Fe + M > 0.14)	136
1.2.1.2.1.1	Crystal structure and nanostructure	136
1.2.1.2.1.2	Magnetic properties	138
1.2.1.2.1.3	Nuclear gamma resonance (NGR) data	144
1.2.1.2.1.4	Electrochemical properties	144
1.2.1.2.1.5	Mechanical properties	145
1.2.1.2.2	R,R'-deficient (Fe,M)-B-based nanocomposites (R,R'/Fe + M < 0.14)	146
1.2.1.2.2.1	Low boron content (B ≤ 7 at-%)	146
1.2.1.2.2.1.1	Crystal structure and nanostructure	146
1.2.1.2.2.1.2	Magnetic properties	150
1.2.1.2.2.1.3	Nuclear gamma resonance (NGR) data	176
1.2.1.2.2.1.4	Positron annihilation data	177
1.2.1.2.2.1.5	Electronic properties	179
1.2.1.2.2.1.6	Corrosion properties	179
1.2.1.2.2.1.7	Mechanical properties	179
1.2.1.2.2.2	High boron content (B > 7 at-%)	179
1.2.1.2.2.2.1	Crystal structure and nanostructure	179
1.2.1.2.2.2.2	Magnetic properties	184
1.2.1.2.2.2.3	Nuclear gamma resonance (NGR) data	198
1.2.1.2.2.2.4	Electronic properties	200
	References	201

1.2.1.3	(R,R') ₂ (Fe,M) ₁₄ B-based hybrid magnets	207
1.2.1.3.1	Crystal structure and nanostructure	207
1.2.1.3.2	Magnetic properties	207
	References	210
1.2.2	(R,R') ₂ (Fe,M) ₁₄ C type	211
1.2.2.1	Crystal structure and nanostructure	211
	References	212
1.2.2.2	Magnetic properties	213
	References	214
1.3	Sm-Fe-based and connected R-Fe-based materials (R = Nd, Pr)	215
	References	216
1.3.1	SmFe ₃ -based nanocrystalline alloys	217
1.3.1.1	Crystal structure and lattice parameters	217
	References	218
1.3.1.2	Magnetic properties	219
	References	220
1.3.2	Sm ₅ Fe ₁₇ -based alloys	221
1.3.2.1	Crystal structure and lattice parameters	221
	References	222
1.3.2.2	Magnetic properties	223
	References	227
1.3.3	R _{1-s} (Fe,M,M') _{5+2s} -type (R = Nd, Pr, Sm) family	228
	References	229
1.3.3.1	Equilibrium nanocrystalline rhombohedral $R\bar{3}m$ Sm ₂ (Fe,M) ₁₇ -derived alloys Sm ₂ Fe _{17-x} M _x X _ε (x > 0; ε ≥ 0), or R _{1-s} (Fe,M,M') _{5+2s} -type family (s = 0.33), or R _x (Fe,M,M') _{100-x} X _ε alloys (x = 10.5 at-% R)	230
1.3.3.1.1	Crystal structure, lattice parameters, nanostructure	231
1.3.3.1.2	Magnetic properties	239
1.3.3.1.3	Nuclear gamma resonance (NGR) data	248
	References	254
1.3.3.2	Equilibrium nanocrystalline tetragonal $I4/mmm$ R(Fe,M,M') ₁₂ -derived alloys R(Fe,M,M') ₁₂ X _ε (R = Nd, Pr, Sm; M' = stabilizing element; X = N, C; ε ~ 1...1.5 for R = Nd, Pr; ε = 0 for R = Sm), or R _{1-s} (Fe,M,M') _{5+2s} X _ε -type family (s = 0.5), or R _x (Fe,M,M') _{100-x} X _ε alloys (x = 7.69 at-% R)	256
1.3.3.2.1	Crystal structure, lattice parameters, nanostructure	256
1.3.3.2.2	Magnetic properties	260
1.3.3.2.3	Nuclear gamma resonance (NGR) data	271
	References	274
1.3.3.3	Out-of-equilibrium nanocrystalline hexagonal $P6/mmm$ -derived alloys Sm(Fe,M) ₉ X _δ (X = N, C; δ > 0), and R(Fe,M,M') ₁₀ X _η alloys (η > 0 for R = Nd, Pr; η = 0 for R = Sm), or R _{1-s} (Fe,M,M') _{5+2s} X _{δ,η} -type alloys (s = 0.36...0.38 and 0.42), or R _x (Fe,M,M') _{100-x} X _{δ,η} -type alloys (x = 10 at-% and 9.03 at-% R)	276
1.3.3.3.1	Hexagonal $P6/mmm$ Sm(Fe,M) ₉ -derived alloys SmFe _{9-y} M _y X _δ (X = N, C; y and δ ≥ 0), precursors of the rhombohedral $R\bar{3}m$ Sm ₂ (Fe,M) ₁₇ -type alloys, or R _{1-s} (Fe,M) _{5+2s} -type alloys (s = 0.36...0.38), or R _x (Fe,M,M') _{100-x} -type alloys (x = 10 at-% R)	276
1.3.3.3.1.1	Crystal structure, lattice parameters, nanostructure	276
1.3.3.3.1.2	Magnetic properties	282
1.3.3.3.1.3	Nuclear gamma resonance (NGR) data	289
1.3.3.3.2	Hexagonal $P6/mmm$ R(Fe,M) ₁₀ -derived alloys R(Fe,M,M') ₁₀ X _η (R = Nd, Pr; X = N, C; η > 0; R = Sm; η = 0), precursors of the tetragonal $I4/mmm$ R(Fe,M,M') ₁₂ -type alloys, or R _{1-s} (Fe,M) _{5+2s} -type alloys (s = 0.42), or R _x (Fe,M,M') _{100-x} -type alloys (x = 9.03 at-% R)	293

1.3.3.3.2.1	Crystal structure, lattice parameters, nanostructure	293
1.3.3.3.2.2	Magnetic properties	294
1.3.3.3.2.3	Nuclear gamma resonance (NGR) data	294
	References	296
1.4	(R,R')-(Fe,M)-(Al,X) bulk amorphous nanocomposite ferromagnets (R = Nd, Pr, Sm; R' = Ce, Y; M = Co, Ni, Cu; X = Si, B)	298
	References	296
1.4.1	R-(Fe,M)-(Al,Si) (R = Nd, Pr, Sm; M = Co, Ni, Cu)	300
1.4.1.1	Structural and nanostructural characteristics	300
	References	302
1.4.1.2	Thermodynamic characteristics	303
	References	305
1.4.1.3	Magnetic properties and nanostructure	306
	References	317
1.4.1.4	Nuclear gamma resonance (NGR) data	318
	References	320
1.4.2	R-(Fe,M)-(Al,B) type (R = Nd, Pr; M = Co, Cu)	321
1.4.2.1	Structural and nanostructural characteristics	321
	References	323
1.4.2.2	Thermodynamic characteristics	324
	References	325
1.4.2.3	Magnetic properties and nanostructure	326
	References	330
1.4.2.4	Nuclear gamma resonance (NGR) data	331
	References	333