

Phase diagram of Sm–Nd–Fe ternary system

Bo-wen WANG^{1,2}, Wen-mei HUANG¹, Zhi-chao JI¹, Zhi-hua WANG¹, Ying SUN¹, Ling WENG¹

1. Province–Ministry Joint Key Laboratory of Electromagnetic Field and Electrical Apparatus Reliability, Hebei University of Technology, Tianjin 300130, China;
2. International Center for Materials Physics, Chinese Academy of Sciences, Shenyang 110016, China

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Abstract: Phase equilibria of the Sm–Nd–Fe ternary system were determined in an isothermal section of 500 °C and vertical sections of $\text{SmFe}_2\text{–NdFe}_2$ and $(\text{Sm}_{0.86}\text{Nd}_{0.12})\text{Fe}_x$ ($1.6 \leq x \leq 2.4$) by optical microscopy, X-ray diffraction analysis, electron probe microanalysis (EPMA), and differential thermal analysis (DTA) techniques. There are four intermetallic phases: $(\text{Sm},\text{Nd})\text{Fe}_2$, $(\text{Sm},\text{Nd})\text{Fe}_3$, $(\text{Sm},\text{Nd})_5\text{Fe}_{17}$ and $(\text{Sm},\text{Nd})_2\text{Fe}_{17}$ in the Sm–Nd–Fe ternary system, and no $(\text{Sm},\text{Nd})_6\text{Fe}_{23}$ phase exists in this system. The isothermal section of 500 °C possesses 7 single-phase regions, 8 two-phase regions, and 4 three-phase regions. The vertical section of $\text{SmFe}_2\text{–NdFe}_2$ contains 2 single-phase regions, 4 two-phase regions, and 7 three-phase regions, and that of $(\text{Sm}_{0.86}\text{Nd}_{0.12})\text{Fe}_x$ consists of 2 single-phase regions, 5 two-phase regions, and 2 three-phase regions. The peritectic temperatures for $(\text{Sm}_{1-x}\text{Nd}_x)\text{Fe}_2$ alloys decrease with increasing the Nd content when $x \leq 0.5$, and the substitution of Nd for Sm makes the stability of $(\text{Sm},\text{Nd})\text{Fe}_2$ phase decrease.

Key words: Sm–Nd–Fe system; phase diagram; structure; compound

1 Introduction

Intermetallic compounds of rare-earth and transition metal have been widely utilized as permanent magnets, magnetostrictive materials, and magnetic recording media. Among these systems, the Sm–Fe system has been the focus of considerable attention and extensive studies because its compounds have high spontaneous magnetization and remain magnetic at relative high temperatures [1,2]. In actual magnets, other rare-earth elements are added in order to induce special magnetic properties. For example, the replacement of Sm by Dy or Nd in SmFe_2 compound can make the magnetocrystalline anisotropies of RFe_2 compounds reduced because the magnetocrystalline anisotropies are dominated by the rare-earth ions. The investigation of the magnetostriction and anisotropy compensation for $\text{Sm}_{1-x}\text{Nd}_x\text{Fe}_2$ [3] and $\text{Sm}_{0.88}\text{Nd}_{0.12}(\text{Fe}_{1-x}\text{Co}_x)_{1.93}$ [4] has found that the $(\text{Sm},\text{Nd})\text{Fe}_2$ compounds possess very high saturation magnetostriction. Structure, magnetic properties and magnetostriction of $\text{Sm}_{1-x}\text{Nd}_x\text{Fe}_{1.55}$ alloys were studied in Ref. [5], and it was found that the alloys with $0 \leq x \leq 0.48$ contain mainly cubic Laves phase, besides minor rare

earths. However, the metallurgical process of Sm–Fe alloys is very complex [6] and it is necessary to have the knowledge of solidification process of Sm–Nd–Fe alloys. Therefore, it is interesting to investigate the phase diagram of the Sm–Nd–Fe ternary system in order to develop a new type of magnetostrictive material and permanent magnetic rare earth-iron alloys.

The Sm–Fe binary system contains SmFe_2 , SmFe_3 and $\text{Sm}_2\text{Fe}_{17}$ phases [7,8]. Two phases, $\text{Nd}_3\text{Fe}_{17}$ and $\text{Nd}_2\text{Fe}_{17}$, exist in the Nd–Fe system [7,8], nevertheless, the cubic Laves compound NdFe_2 has been successfully prepared by high pressure technique. There are $\alpha\text{-Nd}$ and $\alpha\text{-Sm}$ phases in the Sm–Nd system at room temperature [7]. The crystallographic data of their compounds are summarized in Table 1 [7–9]. Up to now, the phase diagram of the Sm–Nd–Fe ternary system has not been published. In this work, the isothermal section of 500 °C, and vertical sections of $\text{SmFe}_2\text{–NdFe}_2$ and $(\text{Sm}_{0.86}\text{Nd}_{0.12})\text{Fe}_x$ ($1.6 \leq x \leq 2.4$) are investigated for the Sm–Nd–Fe ternary system.

2 Experimental

Alloys were prepared from materials with the

Table 1 Crystallographic data of compounds in Sm–Fe and Nd–Fe binary systems

Compound	Pearson symbol	Space group	Structure type	Refs.
SmFe ₂ , NdFe ₂	<i>cF</i> 24	<i>Fd</i> $\bar{3}m$	MgCu ₂	[7,8]
SmFe ₃	<i>hP</i> 24	<i>R</i> $\bar{3}m$	PuNi ₃	[7,8]
Sm ₆ Fe ₂₃	<i>cF</i> 116	<i>Fd</i> $\bar{3}m$	Th ₆ Mn ₂₃	[7,8]
SmFe ₇	<i>tP</i> 68	<i>P</i> 4 ₂ / <i>mn</i> <i>m</i>	–	[7,8]
Nd ₅ Fe ₁₇	<i>hP</i> 264	<i>P</i> 6 ₃ / <i>mcm</i>	Nd ₅ Fe ₁₇	[7–9]
Sm ₂ Fe ₁₇ , Nd ₂ Fe ₁₇	<i>hR</i> 19	<i>R</i> $\bar{3}m$	Th ₂ Zn ₁₇	[7,8]

following purities: Sm, Nd, 99.9% (mass fraction) and Fe 99.8%. Pure metals are made into small pieces, mixed according to the stoichiometry and compacted into pellets. The pellets were heated in an alumina crucible to 400 °C and kept at 400 °C for 10 h under high-purity argon in order to obtain composition-homogenized samples. To compensate for evaporation loss of Sm during melting, 10% more of Sm was added in excess of the stoichiometric amount. Then, they were melted three times in an arc furnace under high-purity argon. During the melting, the melting current should be suitably controlled in order to reduce the loss of Sm. 54 specimens were prepared and the mass loss of each sample was kept below 1%. The as-cast samples wrapped in Mo foil were sealed in silica tube filled with high-purity argon. Specimens were homogenized at different temperatures (Table 2) on the basis of the Sm–Fe and Nd–Fe binary phase diagrams [6–8] and then quenched in water.

Table 2 Composition and heat treatment conditions of alloys in Sm–Nd–Fe system

No.	Alloy	Composition	Heat treatment conditions
1	(Sm _{1-x} Nd _x)Fe ₂	$x=0, 0.1, 0.12, 0.2, 0.3, 0.4, 0.5$	800 °C, 10 d, then 500 °C, 10 d
		$x=0.6, 0.7, 0.8, 0.9, 1.0$	700 °C, 10 d, then 500 °C, 10 d
2	(Sm _{1-x} Nd _x)Fe ₃	$x=0, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 1.0$	750 °C, 10 d, then 500 °C, 10 d
3	(Sm _{1-x} Nd _x) ₅ Fe ₁₇	$x=0, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 1.0$	750 °C, 10 d, then 500 °C, 10 d
4	(Sm _{1-x} Nd _x) ₆ Fe ₂₃	$x=0, 0.15, 0.3, 0.5, 0.75, 1.0$	800 °C, 10 d, then 500 °C, 10 d
5	(Sm _{1-x} Nd _x) ₂ Fe ₁₇	$x=0, 0.15, 0.3, 0.5, 0.75, 1.0$	1000 °C, 5 d, then 500 °C, 15 d
6	(Sm _{0.86} Nd _{0.12})Fe _x	$x=1.6, 1.7, 1.8, 1.85, 1.9, 1.95$	650 °C, 15 d
		$x=2.0, 2.05, 2.1, 2.2, 2.3, 2.4$	800 °C, 15 d

Characterization of the specimens was performed using optical microscopy. The etchant used was 2% nital. Differential thermal analysis (DTA) was carried out with heating and cooling rates of 10 K/min by using an LCP-1-type high temperature differential thermal dilatometer. The DTA furnace was evacuated with a pressure of 5×10^{-3} Pa and then kept under high-purity argon atmosphere in order to prevent the oxidation of samples in the alumina crucibles during the experiment. Pure Cu (99.99%) was used to check the temperature. X-ray diffraction analysis was carried out in a D/max-rA diffractometer equipped with a pyrolytic graphite monochromator. Cu K α radiation was used. Software Jade 5.0 was used to analyze the XRD data of all samples. Electron probe microanalysis (EPMA) was performed in a Camebax-micro analyzer.

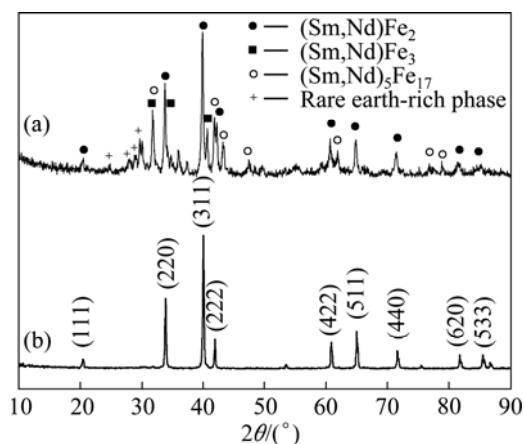
3 Results and discussion

3.1 Intermetallic phases

Metallographic examination, X-ray diffraction analysis, and EPMA confirm that there are four intermetallic phases: (Sm,Nd)Fe₂, (Sm,Nd)Fe₃, (Sm,Nd)₅Fe₁₇ and (Sm,Nd)₂Fe₁₇.

3.1.1 (Sm,Nd)Fe₂

According to Sm–Fe and Nd–Fe systems, SmFe₂ phase is stable, and the NdFe₂ phase does not exist. Metallographic examination and X-ray diffraction analysis confirm that the structure of as-cast (Sm_{1-x}Nd_x)Fe₂ alloys consists of the majority of (Sm,Nd)Fe₂ phase with MgCu₂-type cubic structure when $x \leq 0.55$. Small amounts of phases are the (Sm,Nd)Fe₃ and rare earth-rich phase when $x \leq 0.4$ and the (Sm,Nd)₅Fe₁₇ phase occurs when $x=0.5$ (Fig. 1).

**Fig. 1** X-ray diffraction patterns of as-cast (a) and annealed (b) (Sm_{0.5}Nd_{0.5})Fe₂ alloy

After being annealed, the (Sm_{1-x}Nd_x)Fe₂ alloys are the single (Sm,Nd)Fe₂ phase when $x \leq 0.5$. As we know, the NdFe₂ compound does not exist in the equilibrium

phase diagram and our result shows that only after the sample was annealed at 800 °C for 10 d, the microstructure of $(\text{Sm}_{0.5}\text{Nd}_{0.5})\text{Fe}_2$ alloys becomes a single $(\text{Sm},\text{Nd})\text{Fe}_2$ phase, as shown in Fig. 1(b). PINKERTON et al [10] reported that they were unsuccessful in forming the MgCu_2 -type structure in $\text{Sm}_{0.5}\text{Nd}_{0.5}\text{Fe}_2$ ingots by annealing at 700 °C for 72 h. BABU et al [3] investigated the structure of $\text{Sm}_{1-x}\text{Nd}_x\text{Fe}_{1.93}$ alloys and found that the single $(\text{Sm},\text{Nd})\text{Fe}_2$ phase with the cubic Laves phase structure is at $x=0.32$ and a small quantity of the $(\text{Sm},\text{Nd})\text{Fe}_3$ phase is observed for the $x=0.36$. The structural, magnetic, and magnetostrictive properties of $\text{Tb}_{1-x}\text{Nd}_x(\text{Fe}_{0.9}\text{B}_{0.1})_2$ alloys were investigated in Ref. [11] and it was found that the alloys, homogenized at 700 °C for 7 d, consist predominantly of the cubic Laves phase with a MgCu_2 -type structure and a small amount of rare earth-rich phase when $x \leq 0.55$. Our result indicates that we have successfully obtained the single $(\text{Sm},\text{Nd})\text{Fe}_2$ phase with 50% Nd by suitably annealing. When $x > 0.7$, the main phase becomes $(\text{Sm},\text{Nd})_5\text{Fe}_{17}$ and rare earth-rich phase is a small amount of phase. The $(\text{Sm},\text{Nd})_5\text{Fe}_{17}$, $(\text{Sm},\text{Nd})\text{Fe}_2$, and rare earth-rich phase coexist in the range of $0.5 < x \leq 0.65$. The lattice parameter of the $(\text{Sm},\text{Nd})\text{Fe}_2$ phase for $(\text{Sm}_{1-x}\text{Nd}_x)\text{Fe}_2$ alloys is shown in Fig. 2 and it linearly increases with increasing Nd content up to $x=0.5$. The increase in the lattice parameter is attributed to the large size of Nd atoms (the radius of Nd atom is 0.182 nm, and that of Sm atom is 0.181 nm).

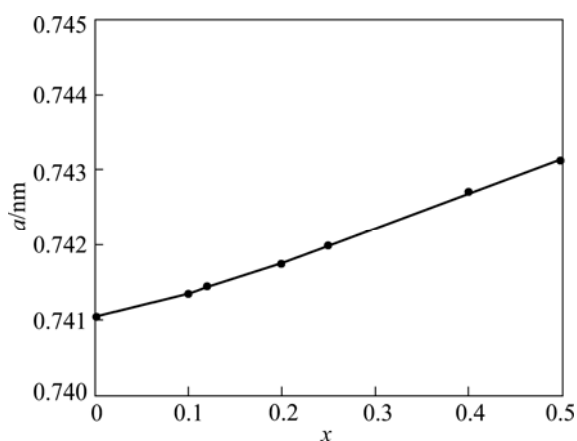


Fig. 2 Composition dependence of lattice parameter of $(\text{Sm},\text{Nd})\text{Fe}_2$ phase for $(\text{Sm}_{1-x}\text{Nd}_x)\text{Fe}_2$ alloys

3.1.2 $(\text{Sm},\text{Nd})\text{Fe}_3$

From the Sm–Fe binary system [7,9], the SmFe_3 phase is stable. However, the NdFe_3 phase does not exist in the Nd–Fe system. X-ray diffraction analysis confirms that the annealed $(\text{Sm}_{1-x}\text{Nd}_x)\text{Fe}_3$ alloys are a single $(\text{Sm},\text{Nd})\text{Fe}_3$ phase with PuNi_3 -type structure when $x < 0.3$. The structure of $(\text{Sm}_{0.6}\text{Nd}_{0.4})\text{Fe}_3$ alloy consists of

$(\text{Sm},\text{Nd})\text{Fe}_2$, $(\text{Sm},\text{Nd})\text{Fe}_3$, and $(\text{Sm},\text{Nd})_5\text{Fe}_{17}$ phases. The $(\text{Sm},\text{Nd})\text{Fe}_3$ phase disappears in the range of $0.5 \leq x \leq 0.6$, the main phase is $(\text{Sm},\text{Nd})_5\text{Fe}_{17}$ and the small amount of second phase is $(\text{Sm},\text{Nd})\text{Fe}_2$, as shown in Fig. 3. With increasing the Nd content further, a small amount of (Sm,Nd) phase appears when $x=0.7$. The structure of $(\text{Sm}_{1-x}\text{Nd}_x)\text{Fe}_3$ alloys consists of duplex phases in the range of $0.8 \leq x \leq 1.0$, the main phase is $(\text{Sm},\text{Nd})_5\text{Fe}_{17}$ and the small amount of second phase is the rare earth-rich phase. This result indicates that the substitution of Nd for Sm makes the stability of $(\text{Sm},\text{Nd})\text{Fe}_3$ phase decrease.

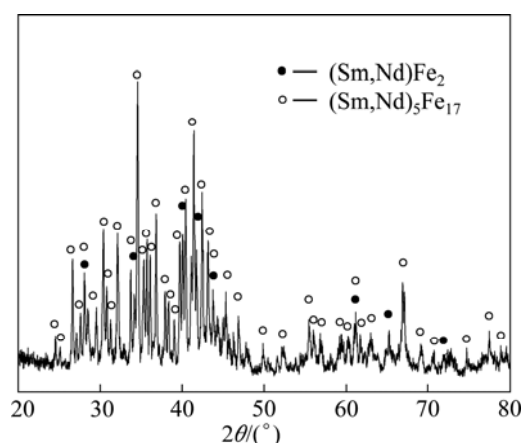


Fig. 3 X-ray diffraction pattern of annealed $(\text{Sm}_{0.4}\text{Nd}_{0.6})\text{Fe}_3$ alloy

3.1.3 $(\text{Sm},\text{Nd})_5\text{Fe}_{17}$

The $\text{Nd}_5\text{Fe}_{17}$ phase is stable only in the Nd–Fe binary system [9] and is of the hexagonal structure. The metallographic examination and X-ray diffraction analysis confirm that the structure of annealed $(\text{Sm}_{1-x}\text{Nd}_x)_5\text{Fe}_{17}$ alloys consists of the $(\text{Sm},\text{Nd})\text{Fe}_3$ phase and a small amount of $(\text{Sm},\text{Nd})_2\text{Fe}_{17}$ phase when $x \leq 0.2$. It was reported that the $\text{Sm}_5\text{Fe}_{17}$ phase cannot be formed in the $\text{Sm}_5\text{Fe}_{17}$ alloy ingot produced by induction melting [12]. By annealing of the amorphous melt-spun ribbon, the $\text{Sm}_5\text{Fe}_{17}$ phase has been synthesized and unlike the $\text{Nd}_5\text{Fe}_{17}$ phase, it is the metastable phase. When $x=0.3$, the $(\text{Sm},\text{Nd})_5\text{Fe}_{17}$ phase appears and the structure consists of the $(\text{Sm},\text{Nd})\text{Fe}_3$, $(\text{Sm},\text{Nd})_5\text{Fe}_{17}$, and $(\text{Sm},\text{Nd})_2\text{Fe}_{17}$ phases. The $(\text{Sm},\text{Nd})\text{Fe}_3$ and $(\text{Sm},\text{Nd})_2\text{Fe}_{17}$ phases disappear and the structure is a single $(\text{Sm},\text{Nd})_5\text{Fe}_{17}$ phase when $x=0.4$. With further increasing the Nd content, the alloys keep a single $(\text{Sm},\text{Nd})_5\text{Fe}_{17}$ phase up to $x=1.0$.

3.1.4 $(\text{Sm},\text{Nd})_6\text{Fe}_{23}$

The $\text{Sm}_6\text{Fe}_{23}$ or $\text{Nd}_6\text{Fe}_{23}$ phase with the $\text{Th}_6\text{Mn}_{23}$ -type structure does not exist in the corresponding system. The X-ray diffraction analysis, metallographic examination, and EPMA (Table 3) have shown that the microstructure of homogenized $(\text{Sm}_{1-x}\text{Nd}_x)_6\text{Fe}_{23}$ alloys consists of $(\text{Sm},\text{Nd})\text{Fe}_3$ and

(Sm,Nd)₂Fe₁₇ phases when $x < 0.25$. In the range of $0.25 \leq x \leq 0.35$, the (Sm,Nd)₅Fe₁₇ phase occurs in addition to (Sm,Nd)Fe₃ and (Sm,Nd)₂Fe₁₇ phases. The structure of homogenized (Sm_{1-x}Nd_x)₆Fe₂₃ alloys consists of (Sm,Nd)₅Fe₁₇ and (Sm,Nd)₂Fe₁₇ phases when $x > 0.4$, and no (Sm_{1-x}Nd_x)₆Fe₂₃ phase occurs in the alloys.

Table 3 EPMA data of Sm₆Fe₂₃, (Sm_{0.85}Nd_{0.15})₆Fe₂₃, and (Sm_{0.7}Nd_{0.3})₆Fe₂₃ alloys

Alloy	Feature	$x/\%$			Phase
		Sm	Nd	Fe	
Sm ₆ Fe ₂₃	Matrix	25.56	—	74.44	SmFe ₃
	Minor phase	10.38	—	89.62	Sm ₂ Fe ₁₇
(Sm _{0.85} Nd _{0.15}) ₆ Fe ₂₃	Matrix	21.07	4.03	74.91	(Sm,Nd)Fe ₃
	Minor phase	9.28	1.71	89.01	(Sm,Nd) ₂ Fe ₁₇
(Sm _{0.7} Nd _{0.3}) ₆ Fe ₂₃	Stick phase	17.62	7.51	74.87	(Sm,Nd)Fe ₃
	Short rod phase	15.94	6.92	77.14	(Sm,Nd) ₅ Fe ₁₇
	Minor phase	7.57	3.25	89.13	(Sm,Nd) ₂ Fe ₁₇

3.1.5 (Sm,Nd)₂Fe₁₇

According to the Sm–Fe and Nd–Fe systems, there are Sm₂Fe₁₇ and Nd₂Fe₁₇ phases. The Sm₂Fe₁₇ phase in annealed Sm₂Fe₁₇ alloy is stable and has a rhombohedral Th₂Zn₁₇ structure. When Nd is substituted for Sm, the miscibility of Sm and Nd of (Sm,Nd)₂Fe₁₇ phase in

annealed (Sm_{1-x}Nd_x)₂Fe₁₇ alloys is unlimited (Fig. 4). This result is in a good agreement with that reported in Ref. [13].

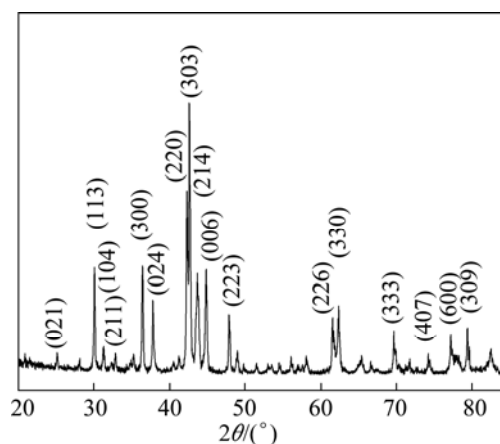


Fig. 4 X-ray diffraction pattern of (Sm_{0.6}Nd_{0.4})₂Fe₁₇ alloy

3.2 Isothermal section of 500 °C

The 500 °C isothermal section of the Sm–Nd–Fe ternary system is shown in Fig. 5. This isothermal section consists of 7 single-phase regions: α -Sm, α -Nd, (Sm,Nd)Fe₂, (Sm,Nd)Fe₃, (Sm,Nd)₅Fe₁₇, (Sm,Nd)₂Fe₁₇, and α -Fe; 8 two-phase regions: α -Sm+(Sm,Nd)Fe₂, α -Nd+(Sm,Nd)Fe₂, α -Nd+(Sm,Nd)₅Fe₁₇, (Sm,Nd)Fe₂+(Sm,Nd)Fe₃, (Sm,Nd)Fe₂+(Sm,Nd)₅Fe₁₇, (Sm,Nd)₅Fe₁₇+(Sm,Nd)₂Fe₁₇, (Sm,Nd)Fe₃+(Sm,Nd)₂Fe₁₇, and (Sm,Nd)₂Fe₁₇+ α -Fe; 4 three phase regions: α -Nd+ α -Sm+(Sm,Nd)Fe₂, α -Nd+(Sm,Nd)Fe₂+(Sm,Nd)₅Fe₁₇, (Sm,Nd)Fe₂+(Sm,Nd)Fe₃+(Sm,Nd)₅Fe₁₇, and (Sm,Nd)Fe₃+

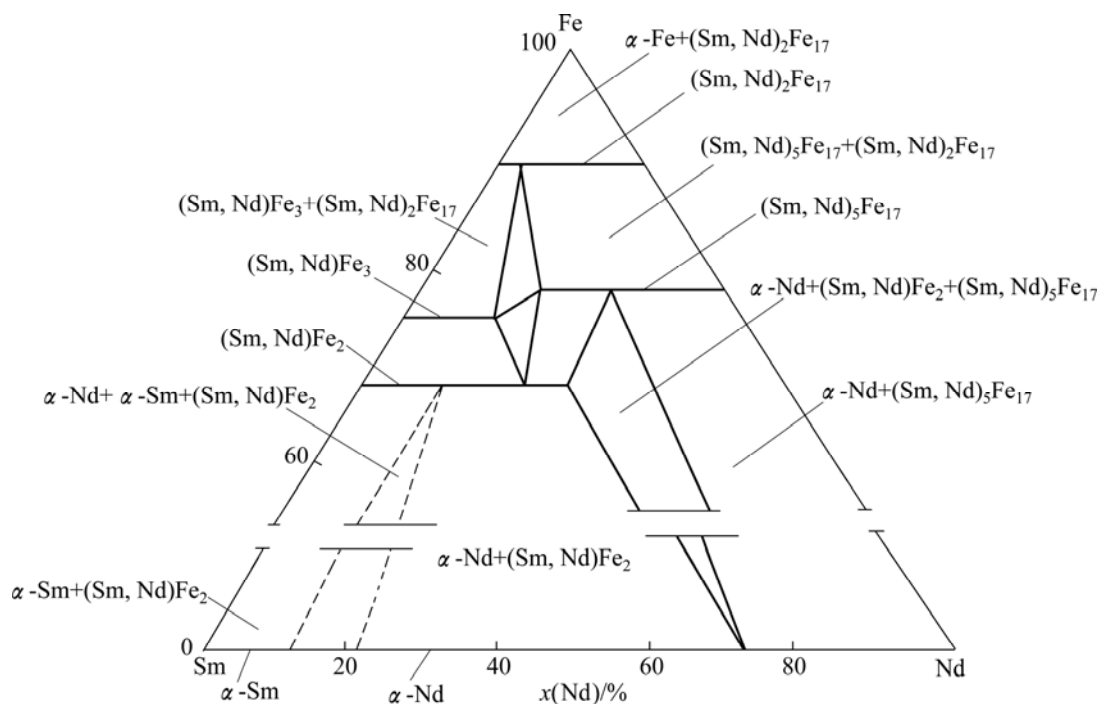


Fig. 5 Isothermal section of Sm–Nd–Fe ternary system at 500 °C

(Sm,Nd)₅Fe₁₇+(Sm,Nd)₂Fe₁₇. The isothermal section of Sm–Nd–Fe ternary system contains (Sm,Nd)₅Fe₁₇ phase, and the homogeneity range of (Sm,Nd)Fe₃ phase is less than that of (Sm,Nd)Fe₂ phase.

3.3 Vertical section of SmFe₂–NdFe₂

The DTA curves for (Sm_{1-x}Nd_x)Fe₂ samples are shown in Fig. 6, and the peritectic reaction temperature and melting temperature can be determined. Based on the results of DTA, optical metallography and X-ray diffraction, a vertical section of the SmFe₂–NdFe₂ in Sm–Nd–Fe ternary system is tentatively drawn in Fig. 7. It consists of 2 single-phase regions: *L* and (Sm,Nd)Fe₂; 4 two-phase regions: *L*+(Sm,Nd)Fe₃, *L*+(Sm,Nd)₅Fe₁₇, *L*+(Sm,Nd)₂Fe₁₇, and α-Nd+(Sm,Nd)₅Fe₁₇; and 7 three-phase regions: *L*+(Sm,Nd)Fe₃+(Sm,Nd)₂Fe₁₇, *L*+(Sm,Nd)₅Fe₁₇+(Sm,Nd)₂Fe₁₇, *L*+(Sm,Nd)Fe₃+(Sm,Nd)₅Fe₁₇, *L*+(Sm,Nd)Fe₂+(Sm,Nd)Fe₃, *L*+(Sm,Nd)Fe₂+(Sm,Nd)₅Fe₁₇, *L*+α-Nd+(Sm,Nd)₅Fe₁₇, and α-Nd+(Sm,Nd)Fe₂+(Sm,Nd)₅Fe₁₇.

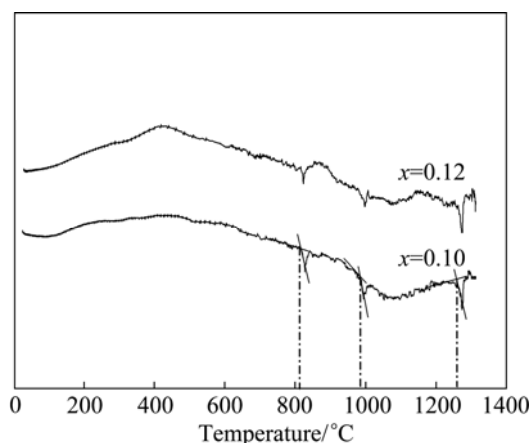


Fig. 6 DTA heating curves for (Sm_{1-x}Nd_x)Fe₂ samples

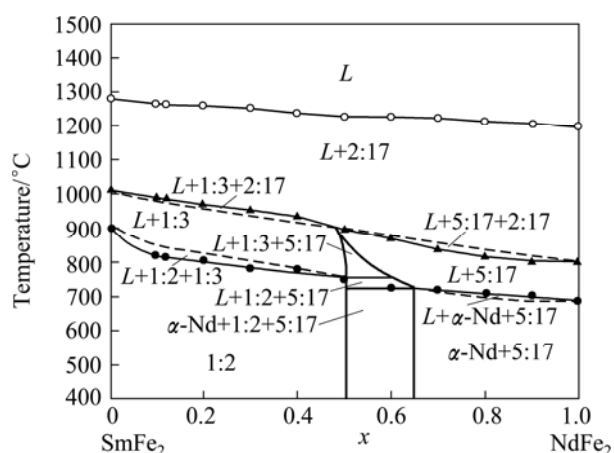


Fig. 7 Vertical section of SmFe₂–NdFe₂ in Sm–Nd–Fe ternary system (*L*=Liquid, 1:2=(Sm,Nd)Fe₂, 1:3=(Sm,Nd)Fe₃, 5:17=(Sm,Nd)₅Fe₁₇, 2:17=(Sm,Nd)₂Fe₁₇)

The peritectic temperatures of *L*+(Sm, Nd)Fe₃→(Sm,Nd)Fe₂ for (Sm_{1-x}Nd_x)Fe₂ alloys decrease with

increasing the Nd content when $x \leq 0.5$, which indicates that the substitution of Nd for Sm makes the stability of (Sm,Nd)Fe₂ phase decrease. From Fig. 7, the temperature range between the reaction of *L*+(Sm,Nd)₂Fe₁₇→(Sm,Nd)Fe₃ and reaction of *L*+(Sm,Nd)Fe₃→(Sm,Nd)Fe₂ becomes larger from $x=0$ to $x=0.12$, and it is difficult to prepare the orientation (Sm_{0.88}Nd_{0.12})Fe₂ sample. This result is consistent with that reported in Ref. [6].

3.4 Vertical section of (Sm_{0.88}Nd_{0.12})Fe_x (1.6≤x≤2.4)

The vertical section of (Sm_{0.88}Nd_{0.12})Fe_x (1.6≤ x ≤2.4) in the Sm–Nd–Fe system is shown in Fig. 8. It consists of 2 single-phase regions: *L* and (Sm,Nd)Fe₂; 5 two-phase regions: *L*+(Sm,Nd)Fe₂, *L*+(Sm,Nd)Fe₃, *L*+(Sm,Nd)₂Fe₁₇, α-Sm+(Sm,Nd)Fe₂, and (Sm,Nd)Fe₂+(Sm,Nd)Fe₃; 2 three-phase regions: *L*+(Sm,Nd)Fe₃+(Sm,Nd)₂Fe₁₇, and *L*+(Sm,Nd)Fe₂+(Sm,Nd)Fe₃. According to the optical metallography and differential thermal analysis, the microstructure of (Sm_{0.88}Nd_{0.12})Fe₂ alloy is a single phase (Sm,Dy)Fe₂ and its peritectic temperature is 815 °C.

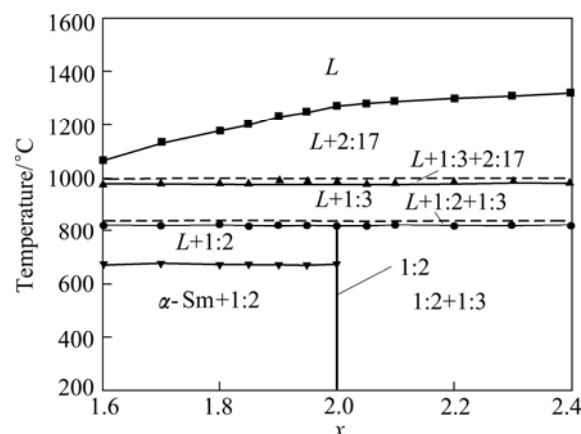


Fig. 8 Vertical section of Sm_{0.88}Nd_{0.12}Fe_x in range of 1.6≤ x ≤2.4 in Sm–Nd–Fe ternary system (*L*=Liquid, 1:2=(Sm,Nd)Fe₂, 1:3=(Sm,Nd)Fe₃, 2:17=(Sm,Nd)₂Fe₁₇)

4 Conclusions

The 500 °C isothermal section of the Sm–Nd–Fe ternary system consists of 7 single-phase regions, 8 two-phase regions and 4 three-phase regions. The complete miscibility of Sm and Nd is found for the (Sm,Nd)₂Fe₁₇ phase, whereas only limited Nd exists in (Sm,Nd)Fe₂, (Sm,Nd)Fe₃, and (Sm,Nd)₅Fe₁₇. No (Sm,Nd)₆Fe₂₃ phase occurs in the system. The vertical section of the SmFe₂–NdFe₂ in Sm–Nd–Fe ternary system consists of 2 single-phase regions, 4 two-phase regions and 7 three-phase regions. The peritectic temperature for (Sm_{1-x}Nd_x)Fe₂ alloys decreases with increasing the Nd content when $x \leq 0.5$. The temperature

range between the reaction of $L+(\text{Sm,Nd})_2\text{Fe}_{17} \rightarrow (\text{Sm,Nd})\text{Fe}_3$ and reaction of $L+(\text{Sm,Nd})\text{Fe}_3 \rightarrow (\text{Sm,Nd})\text{Fe}_2$ becomes larger from $x=0$ to $x=0.12$, and it is difficult to prepare the orientation $(\text{Sm}_{0.88}\text{Nd}_{0.12})\text{Fe}_2$ sample.

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Sm–Nd–Fe 三元系相图

王博文^{1,2}, 黄文美¹, 纪志超¹, 王志华¹, 孙英¹, 翁玲¹

1. 河北工业大学 电磁场与电器可靠性省部共建重点实验室, 天津 300130;
2. 中国科学院 国际材料物理中心, 沈阳 110016

摘 要: 采用金相显微镜、X 射线衍射、电子探针和差热分析等技术确定了 Sm–Nd–Fe 三元系相图, 包含 Sm–Nd–Fe 三元系 500 °C 等温截面、 SmFe_2 – NdFe_2 变温截面和 $(\text{Sm}_{0.88}\text{Nd}_{0.12})\text{Fe}_x$ ($1.6 \leq x \leq 2.4$) 变温截面。Sm–Nd–Fe 三元系含有 4 种金属间化合物: $(\text{Sm,Nd})\text{Fe}_2$, $(\text{Sm,Nd})\text{Fe}_3$, $(\text{Sm,Nd})_3\text{Fe}_{17}$, $(\text{Sm,Nd})_2\text{Fe}_{17}$, 不含 $(\text{Sm,Nd})_6\text{Fe}_{23}$ 相。500 °C 等温截面含有 7 个单相区, 8 个两相区, 4 个三相区。 SmFe_2 – NdFe_2 变温截面含有 2 个单相区, 4 个两相区, 7 个三相区。 $(\text{Sm}_{0.88}\text{Nd}_{0.12})\text{Fe}_{1.6}$ – $(\text{Sm}_{0.88}\text{Nd}_{0.12})\text{Fe}_{2.4}$ 含有 2 个单相区, 5 个两相区, 2 个三相区。当 $x \leq 0.5$ 时, $(\text{Sm}_{1-x}\text{Nd}_x)\text{Fe}_2$ 合金的包晶转变温度随着 Nd 含量的增加而降低, 表明以 Nd 代替 Sm 从而使 $(\text{Sm,Nd})\text{Fe}_2$ 相的稳定性降低。

关键词: Sm–Nd–Fe 系; 相图; 结构; 化合物

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