INTERACTION OF THE ALLOY BASED ON $SmCo_5$ COMPOUND WITH HYDROGEN AT PRESSURES 0.1-0.66 MPa

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Introduction

Hydrogen treatment of materials has wide practical application [1]. It has impotent place at the production of magnets based on $R_2Fe_{14}B$ alloy, where this treatment are used for both the production of powders [2], and the change of structure by means of hydrogenation, disproportionation, desorption, recombination (HDDR) [3]. The HDDR is also investigated in ferromagnetic alloys based on Sm-Co system, but in this case it is necessary high hydrogen pressures (3...5 MPa) [4,5]. A low hydrogen pressure is more favoured from the practical viewpoint. The interaction of KC37 commercial alloy with hydrogen at pressures 0.1…0.66 MPa and temperatures up to 960 °C was studied for the estimation of possibility of phase transformations in Sm-Co alloys under hydrogen at relatively low pressures. Differential thermal (DTA) and X-ray phase analyses were used. The initial alloy contains $SmCo_5$ ferromagnetic phase and impurity $SmCo_3$ phase. The KC37-H_2 system was heated from room temperature and cooled to this temperature in hydrogen at initial pressure 0.1 MPa to 885 °C; 0.2 MPa to 890 °C; 0.3 MPa to 925 °C; 0.4 MPa to 860 °C; 0.5 MPa to 200, 500, 600, 900 and 960 °C; 0.64 and 0.66 MPa to 960 °C (table).

Results and discussion

X-ray phase analysis of interaction products in KC37-H_2 system. The impurity $SmCo_3$ phase decomposes into an unknown phase after heating of the alloy in hydrogen at P_{H_2}=0.1 MPa (table). The $SmCo_5$ ferromagnetic phase continues stable at P_{H_2}=0.2 MPa (table). The SmH_x hydride was observed among disproportionation products of $SmCo_3$ at these conditions. In our assumption, the amorphous or nanodimension cobalt is also presented in the sample and gives increased phone in the XRD pattern in the angle 50...60°. The SmH_x and Sm_2Co_{17} were observed in the composition of sample in the place of $SmCo_3$ at P_{H_2}=0.3 MPa (Fig. *a*). The analogous phase composition was found at P_{H_2}=0.4 MPa (Fig. *b*). However, the amount of SmH_x and Sm_2Co_{17} phases increases at these conditions, while the relatively amount of $SmCo_5$ decreases. The following increase of pressure to P_{H_2}=0.5 MPa leads to the decrease of relatively amount of SmH_x and Sm_2Co_{17} phases (Fig. *c*) comparatively with the above sample. The holding of sample for 5 h at the above conditions results in the full transformation of Sm_2Co_{17} into $SmCo_5$ (Fig *d*). Besides, a small amount of SmH_x and Co is presented (table).

The analogous composition of interaction products was found at P_{H_2}=0.64 and 0.66 MPa (table).

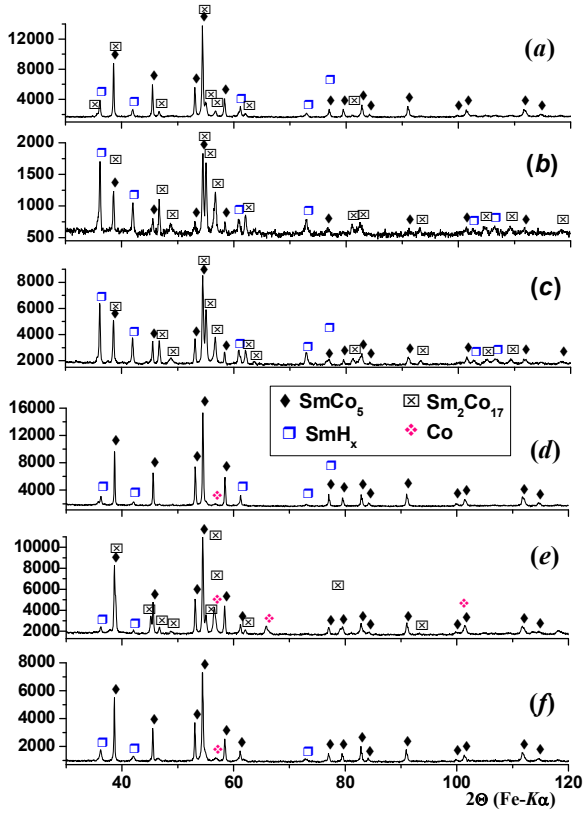

Figure. XRD patterns of the interaction products in KC37-H_2 system: ***a*** – 0.3 MPa; ***b*** – 0.4 MPa; ***c*** – 0.5 MPa, T_{max}=900 °C, τ=0 h.; ***d*** – 0.5 MPa, T_{max}=900 °C, τ=5 год.; ***e*** – 0.64 MPa, T_{max}=950 °C, τ=0; ***f*** – 0.66 MPa, T_{max}=950 °C, τ=0.5 h.

In the accordance to $SmCo_5$, a small amount of SmH_x hydride and Sm_2Co_{17} was observed after heating of the sample in hydrogen without holding (Fig. *e*). The holding for 0.5 h at P_{H_2}=0.66 MPa leads to the formation of the same phase composition as after

Table. Conditions and interaction products in KC37-H_2 system

Treatment conditions			Phase	Lattice constants, nm	
P, MPa	T_{max}, °C	T, h		a	c
Initial alloy			$SmCo_5$ $SmCo_3$	0.4980(3) 0.5006(2)	0.3954(3) 2.4210(7)
0.1	885		$SmCo_5$?	0.5007(1)	0.3968(1)
0.2	890		$SmCo_5$ SmH_x	0.50061(6) 0.5404(6)	0.39661(7)
0.3	925		$SmCo_5$ SmH_x γ-Sm_2Co_{17}	0.50024(4) 0.5395(1) 0.8467(2)	0.39702(5) 1.2219(5)
0.4	860		$SmCo_5$ γ-Sm_2Co_{17} SmH_x	0.5003(2) 0.8464(2) 0.5405(1)	0.3969(2) 1.2227(4)
0.5	200		$SmCo_5$?	0.50035(7)	0.39674(8)
0.5	500		$SmCo_5$?	0.50033(6)	0.39659(7)
0.5	600		$SmCo_5$ SmH_x Co	0.5007(2) 0.5398(2) 0.3544(1)	0.3971(2)
0.5	895	0	$SmCo_5$ γ-Sm_2Co_{17} SmH_x	0.49999(4) 0.8453(2) 0.54015(7)	0.39713(7) 1.2225(4)
0.5	900	5	$SmCo_5$ SmH_x	0.50073(9) 0.5394(6)	0.39704(9)
0.5	960	1	$SmCo_5$ γ-Sm_2Co_{17} β-Co ?	0.5002(2) 0.8458(3) 0.3542(1)	0.3960(2) 1.2203(7)
0.5	960	2	$SmCo_5$ γ-Sm_2Co_{17} Co ?	0.4998(1) 0.8462(4) 0.3542(2)	0.3969(2) 1.2209(7)
0.5	960	5	$SmCo_5$ γ-Sm_2Co_{17} Co ?	0.5001(2) 0.8462(4) 0.3541(2)	0.3968(2) 1.2209(7)
0.64	950	0	$SmCo_5$ γ-Sm_2Co_{17} SmH_x Co ?	0.50033(4) 0.8456(3) 0.5399(2) 0.3541(2)	0.39690(5) 1.2226(7)
0.66	960	0.5	$SmCo_5$ SmH_x Co	0.50063(3) 0.5406(2) –	0.39683(3)

the heating at P_{H_2}=0,5 МПа with holding for 5 h (Fig. *f*).

It was determined, that phase composition in alloy-hydrogen system at P_{H_2}=0.5 MPa depends on heating temperature. Three phase transformations were observed by means of DTA: two endothermic at 250 and 775 °C and exothermic at 560 °C. The phase with $CaCu_5$-type structure were found among disproportionation products at 200 and 500 °C by means of X-ray phase analysis (table), though the both samples contain also unknown phase(s). Theirs amount decreases with the rise of temperature. The mixture of SmH_x and Co with the remains of $SmCo_5$ ferromagnetic phase was obtained at 600 °C (table). The increase of interaction temperature to 960 °C with holding for 1, 2, 5 h results in the formation of different products composition than after reaction at 900 °C (P_{H_2}=0.5 MPa). First difference: samarium hydride decomposes at these conditions (table). Second: the composition of interaction products is the same after holding for 1, 2 and 5 h: $SmCo_5$, Sm_2Co_{17} and Co and quantitative correlation between phase's remains without change.

Conclusions

The changes of the composition of the alloy, which contains $SmCo_5$ and $SmCo_3$, in hydrogen at pressure 0.1-0.66 MPa and temperature up to 960 °C were determined. The interaction products are: SmH_x, Co, $SmCo_5$, Sm_2Co_{17} and unknown phases. The composition of interaction products depends on initial hydrogen pressure, temperature and holding time at the highest temperature. The $SmCo_3$ phase decomposes in hydrogen at $P_{H_2} \geq 0.1$ MPa.

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