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Abstract

Full Text

Chemistry

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STUDY OF THE SYSTEMS

COBALT–CARBON AND NICKEL–CARBON

The Co–C and Ni–C systems have been insufficiently studied–only up to contents not exceeding 25 at.% carbon ([1]). Taking this into account, the above systems were experimentally studied in the region of higher carbon contents and at higher temperatures, analogously to the study of the Fe–C system ([2]).

The alloys were prepared from cobalt (98.5%) and nickel (99.8%) and saturated with carbon during isothermal holding in crucibles made of pure graphite. The temperature was measured with an optical pyrometer. The limiting solubility of carbon in liquid cobalt or nickel at a given temperature was determined from the carbon content in an alloy quenched from the saturation temperature in water. The compositions of the alloys obtained are given in Table 1.

Table 1

Carbon content in the alloys studied

No.	Saturation temperature, °C	Holding time, min	C content, wt.%	C content, at.%
Co–C	**Co–C**	**Co–C**	**Co–C**	**Co–C**
1	1950	5	5.52	22.3
2	2300	5	6.9	26.6
3	2400	10	11.3	38.4
4	2400	10	12.3	40.7
5	2400	15	12.8	41.8
6	2400	25	21.4	57.1
Ni–C	**Ni–C**	**Ni–C**	**Ni–C**	**Ni–C**
1	2300	5	7.35	28.0
2	2300	5	7.8	29.2
3	2400	5	9.1	32.8
4	2400	5	10.2	35.6
5	2500	5	13.3	42.7
6	2500	10	17.9	46.2

No.	Saturation temperature, °C	Holding time, min	C content, wt.%	C content, at.%
7	2500	15	20.2	55.2
8	2500	30	31.5	69.2

The structure of the alloys and their phase composition were established by studying the microstructure (magnification $×$100, $×$500, and $×$1000) and measuring the microhardness of the structural constituents on a PMT-3 instrument with loads of 1 g (graphite), 20 g (solid solution of carbon in the metal, eutectic, and carbides), and 100-200 g (solid solution and eutectic). X-ray structural analysis was performed in a standard RK-5 camera using iron radiation (K_α). The temperature of the phase transformations was determined by thermal analysis with a tungsten differential resistance thermometer. Samples weighing about 1 g were heated to 1300-1400° and cooled at a rate of 40°/min in beryllium oxide crucibles in an atmosphere of pure helium. The results of the study are shown in Fig. 1.

Cobalt undergoes a polymorphic transformation of the close-packed hexagonal α-modification into the close-packed cubic β-modification at 380-400°, a magnetic transformation at 1130°, and melting at 1495-1500°. The boiling point of cobalt lies near 2878°. The solubility of carbon in solid cobalt rises to 4.5% at 1320°, and in the liquid—to 28% at 2415°. The eutectic, consisting of a solid solution of carbon in cobalt and graphite, forms at 12 at.% C and 1320°C. The eutectic horizontal has been traced to 57.1 at.% C (21.4 wt.%); it may be extended to 100% carbon, taking into account the low solubility of cobalt in graphite. The temperature of the magnetic transformation of Co decreases to 1035° upon dissolution of carbon.

Rapid quenching of the alloys in water from the liquid state fixes the carbide eutectic, consisting of a solid solution of carbon in cobalt and Co_3C (Fig. 2a); separate regions of primary car-

Fig. 2. Microstructure of alloys ($×$500) of cobalt and nickel with carbon, quenched from 1950-2500° C in water:
a –22.3 at.% C, remainder Co; *b* –26.65 at.% C, remainder Co; *c* –57.1 at.% C, remainder Co; *d* –29.2 at.% C, remainder Ni; *e* –55.2 at.% C, remainder Ni; *f* –69.2 at.% C, remainder Ni.

species. As a result, the lines of the metastable system Co–Co_3C are superimposed on the stable Co–graphite system, just as occurs in the Fe–graphite and Fe–Fe_3C systems. The carbide Co_3C is unstable and decomposes readily on heating to 300-350°, and therefore the Co–Co_3C system is highly metastable.

In the high-temperature region (near 2400°), the melt reaches limiting saturation with carbon, and, owing to the boiling off of cobalt as the holding time is increased, the alloy may be enriched

Fig. 1. a –phase diagram of Co–C; b –phase diagram of Ni–C

Figure 1: Fig. 1. a –phase diagram of Co–C; b –phase diagram of Ni–C

a *b*

Fig. 1. *a* –phase diagram of Co–C; *b* –phase diagram of Ni–C

with carbon to very high contents (Fig. 2*b*, *c*)–practically to pure graphite.

On the basis of the known data on the boiling point of cobalt (2878°), the sublimation of graphite (3870°), and the boiling of a melt saturated to the limiting extent with carbon in cobalt (~2400°), the upper region of the equilibria of liquid cobalt and graphite with the vapor phase was constructed hypothetically (Fig. 1*a*).

The Ni–C system was studied up to 69.2 at.% C (31.5 wt.% C). Figure 1*b* shows that the stable Ni–graphite system is characterized by the presence of a eutectic horizontal, traced up to 69.2 at.% C, which has been extrapolated to 100% carbon because of the low solubility of the latter in nickel. In quenched alloys (Fig. 2*a*, *d*, *e*) there is a eutectic Ni–Ni_3C (Fig. 2*c*), which on heating transforms into a graphite eutectic. Thus, a metastable system with the very unstable nickel carbide is superimposed on the stable system. As in the Fe–Fe_3C and Co–Co_3C systems, decomposition of the carbide Ni_3C occurs below the melting point (at 200-400°). Taking into account the boiling point of nickel (2900°) and the sublimation of graphite (3870°), the upper part of the system with the vapor phase was constructed. The carbides Co_3C and Ni_3C are less stable than the carbide Fe_3C and decompose already in the solid state; therefore they cannot exist in alloys rich in carbon. The phase diagrams of the three analogous systems (Fe, Co, Ni) with carbon have a common character.

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Note: Figure translations are in progress. See original paper for figures.