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Phase transformations in Fe-B system alloys

N. Yu. Filonenko

Dnipropetrovsk State Medical Academy
natph@mail.ru

It is found that in Fe-B system alloys with boron content 11,0-15,0% (wt.) the phase formation of iron boride Fe_5B_3 is feasible. It is revealed the mechanism of formation and temperature range of iron boride Fe_5B_3 field in Fe-B system alloys with boron content of 11,0-15,0% (wt.), the rest is iron. It is shown that formation of Fe_5B_3 phase results from interaction of liquid with monoboride FeB according to peritectic reaction at the temperature of 1680 K: $L + FeB \rightarrow Fe_5B_3$. It is established that at the temperature of 1420 K the decomposition of boride Fe_5B_3 occurs and results in formation of iron monoboride FeB and iron boride FeB phases.
Keywords: boride Fe_2B, monoboride FeB, boride Fe_5B_3, Fe-B system.

Установлено, что в сплавах системы Fe-B с содержанием бора 11,0-15,0% (мас.) возможно образование борида железа Fe_5B_3. Определен механизм образования и температурный интервал существования боридов железа Fe_5B_3 в сплавах системы Fe-B с содержанием бора 11-15,0% (мас.), остальное - железо. Показано, что образование фазы Fe_5B_3 происходит в результате взаимодействия жидкости и моноборида FeB по перитектической реакции при температуре -1680 К: $L + FeB \rightarrow Fe_5B_3$. Показано, что при температуре 1420 К происходит распад борида Fe_5B_3, следствием которого является образование фаз моноборида железа FeB и борида Fe_2B.
Ключевые слова: борид Fe_2B, моноборид FeB, борид Fe_5B_3, система Fe-B.

Встановлено, що в сплавах системи Fe-B з вмістом бору 11,0-15,0 % (мас.) можливе утворення бориду заліза Fe_5B_3. Визначено механізм утворення та температурний інтервал існування бориду заліза Fe_5B_3 у сплавах системи Fe-B з вмістом бору 11-15,0 % (мас.), інше – залізо. Показано, що утворення фази Fe_5B_3 відбувається в результаті взаємодії рідини та монобориду FeB по перитектичній реакції при температурі 1680 К: $L + FeB \rightarrow Fe_5B_3$. Визначено, що при температурі 1420 К існує розпад бориду Fe_5B_3, наслідком якого є утворення фаз монобориду заліза FeB та бориду заліза Fe_2B.
Ключові слова: борид Fe_2B, моноборид FeB, бориду Fe_5B_3, система Fe-B.

Introduction

Fe-B system alloys exhibit a complex of such unique properties as refractory quality, high hardness, chemical stability in various aggressive environments and others [1]. Despite the fact that study for the structure, mechanical and chemical properties of these alloys has persisted for decades the matter of the phase composition and phase transformations in these alloys remains actual.

It is known that in Fe-B system alloys with boron content over 8,86% (wt.) at the temperature of 1833 K the iron monoboride FeB is formed [2]. At the temperature of 1682 K due to the interaction of liquid with iron monoboride FeB the peritectic transformation $L + FeB \leftrightarrow Fe_2B$ occurs, and as a result the boride Fe_2B is formed [3]. Authors of Refs. [4-5, 6-7] suggest that in Fe-B system alloys there is iron monoboride FeB appearing in two modifications: high-temperature β-FeB and low-temperature α-FeB. According to results represented in Refs. [4, 5] at the temperature of 1400 K the polymorphic transformation $\beta - FeB \rightarrow \alpha - FeB$ takes place. It is known that β-FeB and α-FeB phases differ only in value of magnetic moment [4-7].

In the paper [8] it is shown that in Fe-B system alloys upon boron content of 11,0-15,0% (wt.) the occurrence of metastable boride phase Fe_5B_3 is feasible, but mechanism of its formation is not revealed.

The object of the paper is to determine the structure and phase transformations in Fe-B system alloys.

Materials and methods of investigation

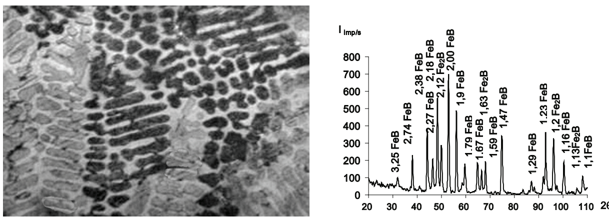
The investigation was performed for the specimens with boron content of 11,0-15,0% (wt.), the rest is iron. To obtain Fe-B system alloys we used the furnace burden of such content: carbonyl iron (with iron content of 99,95% (wt.)), amorphous boron (with boron content of 97,5 % (wt.)). The smelting of specimens was performed in Taman's furmace in alundum saggers in an argon atmosphere. The cooling rate of alloys was 10 K/s. To ascertain the features of phase transformations for Fe-B system alloys we heated alloys up to the temperature of 1820 K and cast into V-shaped molds. The study of phase structure changes depending on heating temperature was performed on facility for investigation for microstructure of materials at high temperatures 'Kyrgyzstan' in argon atmosphere with heating rate of 24 K/min.

To determine the chemical composition we use the chemical and spectroscopic analysis [9]. The microhardness for various phase constituent we measure by means of microhardness gauge PMT-3. The phase composition of alloys we ascertain by X-ray microanalysis on JSM–6490 microscope, as well as by means of optical microscope 'Neophot-21'. The X-ray structure analysis was performed on diffractometer DRON-3 in monochromated Fe-K_α radiation.

Results and discussion

For Fe-B alloys with boron content within the interval of 11,0-15,0% (wt.) we observe the FeB phase dendrites of different colors (Fig. 1, a).

The X-ray structure analysis data show the presence of iron monoboride FeB and iron boride Fe_2B in alloy.



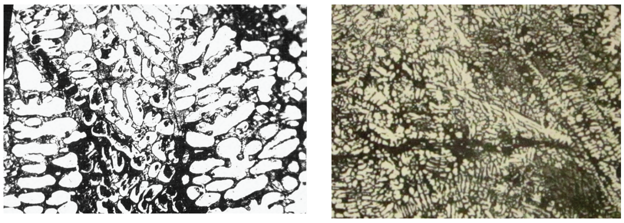
a *b*

Fig. 1. Microstructure (a) and diffractograms of alloy FeB with boron content of 14,0% (wt.).

The occurrence of the monoborides of different colors in the structure of Fe-B system alloys is associated with existence of two modifications of monoboride – the high-temperature modification β-Fe(B,C) and low-temperature α-modification [4-5].

To ascertain the phase transformations which occur during crystallization of alloys the specimens with boron content of 13% (wt.) were heated up to the melting point, namely to 1820 K, and then were casted into V-shaped molds. As a result in the part of a wedge cooled with a rate of 10^2 K/s against white primary boride dendrites we observe two-phase structure areas, which consist of the phases FeB and Fe_2B, as it is proved by X-ray structure analysis data (Fig. 2, a). In the interdendritic space the phase has the same coloring as inside the boride FeB. The analysis of outcomes enables to assume that in alloy the primary phase is monoboride FeB dendrites and dark areas are results of decomposition of the phase Fe_5B_3, occuring as a result of peritectic transformation $L + FeB \to Fe_5B_3$. The increase of cooling rate is followed by formation of more dispersed structure (Fig. 2, b).

To determine the temperature and to check the fact of occurrence the phase transformation we study the annealing of alloy Fe-B with weight content of boron of 12,0% to the temperature of 1490 K on 'Kyrgyzstan' facility in an argon atmosphere illuminated by polarized light.



a *b*

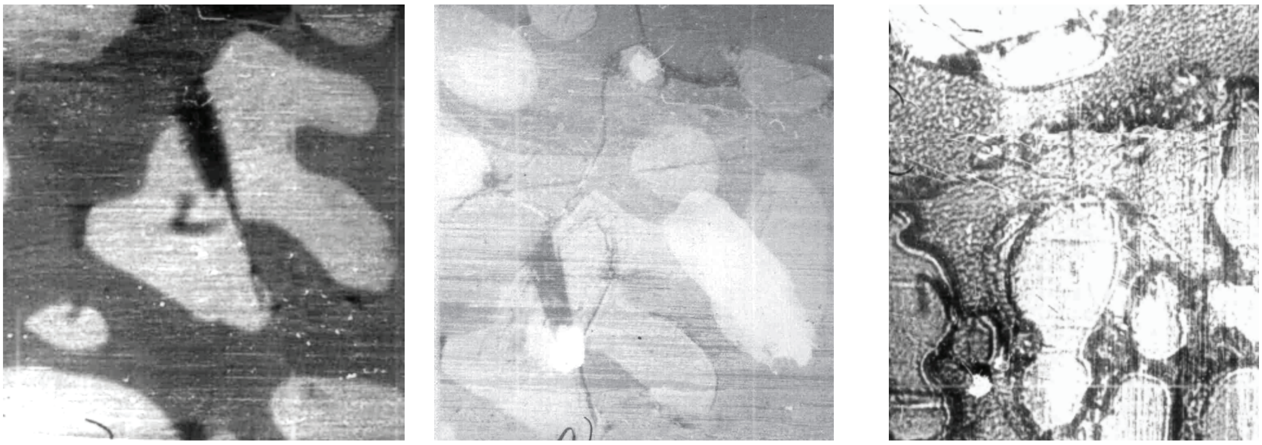
Fig. 2. Microstructure of alloy with boron content of 13% (wt.) at cooling rate of: 10^2 K/s (a), 10^3 K/s (b).

Heating to the temperature below 1390 K does not effect on morphology of phase constituents of alloys. The further heating to the temperature of 1400 K leads to appearance of white inclusions of the size of 2,5-7,5 μm (Fig. 3, b). It should be noted that these inclusions are structurally similar to boride FeB. When the temperature rises to 1450 K we can observe in black monoboride FeB the formation of inclusions of round shape (Fig. 3, c). In white monoborides such process is not observed.

Thus, investigation of alloy structure shows that at the temperature of 1450 K the solid-phase transformation takes place, namely $FeB + Fe_2B \to Fe_5B_3$.

To reveal the phase transformations in Fe-B alloys the differential thermal analysis was carried out. According to obtained results in iron-based alloy with boron content of 12% (wt.) the phase transformation $L \to FeB$ takes place during cooling at the temperature of 1798 K. The possible formation of Fe_5B_3 boride is occurring as a result of peritectic reaction $L + FeB \leftrightarrow Fe_5B_3$ at the temperature of 1739 K. At the temperature of 1421 K we observe a slight heat effect on thermogram, which can show that there is phase transformation $Fe_5B_3 \to FeB + Fe_2B$, occurring in solid state.

The analysis of outcomes enables to assume that iron boride Fe_5B_3 is formed as a result of peritectic transformation $L + FeB \to Fe_5B_3$ at the temperature of 1680 K. At the temperature of 1420 K decomposition of this phase $Fe_5B_3 \to FeB + Fe_2B$ takes place along with formation of iron monoboride FeB and boride Fe_2B. The revealed phase Fe_5B_3 exists within the temperature interval of 1420-1680 K.



a *b* *c*

Fig. 3. Microstructure of Fe-B alloy with boron content of 12,0% (wt.) after hot-stage microscope study: a) 293 K, b) 1400 K, c) 1450 K, x1000.

Conclusions

1. In the paper the phase transformations occurring in Fe-B alloys with boron content over 11,0% (wt.) are studied. The mechanism of formation and temperature interval of existence of iron boride Fe_5B_3 is ascertained in Fe-B system alloys with boron content of 11-15,0% (wt.), the rest is iron.

2. It is ascertained, that at the temperature of 1680 K the formation of Fe_5B_3 phase occurs as a result of peritectic transformation $L + FeB \rightarrow Fe_5B_3$, and decomposition of this phase in a solid state takes place at the temperature of 1420 K along with formation of FeB and Fe_2B phases.

3. It is shown that phase Fe_5B_3 exists in Fe-B system alloys within the temperature interval of 1420-1680 K.

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