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Investigation of pecularities of the structure formation for Fe-B-C system alloys in crystallization

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Is show that in the iron-based alloys with weight content of boron from 1,8-3,5 % and with carbon content from 2-2,5 % (w.) after crystallization the morphology of specimen includes primary dendrites of $Fe_3(CB)$ phase and plate-like eutectics γ-Fe+$Fe_3(CB)$. It is revealed that in the process of Fe-B-C alloys crystallization the formation of cubic boron carbide $Fe_{23}(CB)_6$ takes place as a result of preannealing at the temperature of 1173 K. The formation of $Fe_{23}(CB)_6$ phase occurs on peritectic dissolving of Fe_2B boride, whereas eutectics $Fe_{23}(CB)_6$+γ-Fe is formed as a result of four-phase peritectic transformation L+Fe_2B→$Fe_{23}(CB)_6$+γ-Fe.
Keywords: boride Fe_2B, eutectics , cubic boron carbide $Fe_{23}(CB)_6$ and Fe-B-C system alloy.

Показано, что в сплавах основе железа с содержанием бора 1,8-3,5 % (мас.) и углерода 2-2,5 % (мас.) после кристаллизации микроструктура состоит из первичных дендритов фазы $Fe_3(CB)$ и пластинчатой эвтектики γ-Fe+$Fe_3(CB)$. Установлено, что в процессах кристаллизации сплавов Fe-B-C образование кубического карбида $Fe_{23}(CB)_6$ происходит в результате предварительного отжига при температуре 1173 К. Выделение фазы $Fe_{23}(CB)_6$ осуществляется при перитектическом растворении борида Fe_2B, а формирование эвтектики $Fe_{23}(CB)_6$+γ-Fe происходит в результате четырехфазного перитектического превращения L+Fe_2B→$Fe_{23}(CB)_6$+γ-Fe.
Ключевые слова: борид Fe_2B, эвтектика, кубический борокарбид $Fe_{23}(CB)_6$, система Fe-B-C.

Показано, що у сплавах на основі заліза з вмістом бору 1,8-3,5 % (мас.) та карбону 2-2,5 % (мас.) після кристалізації мікроструктура містить первинні дендрити фази $Fe_3(CB)$ та пластинчату евтектику γ-Fe+$Fe_3(CB)$. Встановлено, що процесі кристалізації сплавів Fe-B-C утворення кубічного борокарбіду $Fe_{23}(CB)_6$ відбувається в результаті відпалу при температурі 1173 К. Виділення фази $Fe_{23}(CB)_6$ здійснюється при перитектичному розчиненні борида Fe_2B, а формування евтектики $Fe_{23}(CB)_6$+γ-Fe відбувається в результаті четирьохфазного перитектичного перетворення L+Fe_2B→$Fe_{23}(CB)_6$+γ-Fe.
Ключові слова: борид Fe_2B, евтектика, кубічний борокрбід $Fe_{23}(CB)_6$, система Fe-B-C.

Introduction

It is well known, that Fe-B-C system alloys are of practical use because of complex of such properties as refractory quality, high hardness, abrasive wear resistance, chemical stability in various aggressive environments and others [1-3]. Available information about phase transitions in Fe-Fe_2B-Fe_3C composition triangle of Fe-B-C system alloys in the process of crystallization from a liquid state goes to prove that equilibrium phases are iron solid solution, boride Fe_2B and boron cementite $Fe_3(CB)$. $Fe_{23}(CB)_6$ compound, which is isomorphic with carbide $Cr_{23}C_6$, for the first time has been described in Ref. [4] as congruently melting phase. According to Refs. [5, 6] phase $Fe_{23}(CB)_6$ exists in a solid state and is not stable at the temperatures above 1230 K. In the paper [7] it was shown that at high degree of supercooling the precipitate of this compound is possible. In Ref. [8] it is ascertained that precipitate of cubic boron carbide $Fe_{23}(CB)_6$ in the process of crystallization from a liquid state takes place after a special pretreatment, which includes thermal cycling in a solid-liquid state for at least 5-6 cycles within the temperature interval of 1123-1613 K, but mechanism of formation of cubic boron carbide $Fe_{23}(CB)_6$ in Fe-B-C alloys is not revealed.

In this paper the investigation of crystallization of alloys of Fe-Fe_2B-Fe_3C composition triangle with preannealing in solid state is carried out and mechanism of formation of cubic boron carbide $Fe_{23}(CB)_6$ is studied.

Materials and methods of investigation

For investigation there are used alloys with weight content of boron from 1,8-3,5 % and with carbon content from 2-2,5 % (w.), the rest is iron. To obtain Fe-B-C alloys we use carbonyl iron (with iron content of 99,95% (w.)), amorphous boron (with boron content of 97,5,0% (w.)) and spectroscopically pure graphite. To prevent a liquation alloys were made from previously well-stirred and pressed powder of furnace burden materials. The specimen smelting was carried out in Taman's furnace with graphite heater, melting of specimens was performed in alundum saggers under argon atmosphere. The cooling rate of initial

a *b* *c*

Fig. 1. Microstructure of Fe-B-C alloy with boron content of 2,95 % (w.), carbon content of 2,3 % (w.): a) after smelting x400, b) after pretreatment x100, c) eutectics γ-Fe+ $Fe_{23}(CB)_6$.

specimens of alloys was 50 K/s. To determine alloy chemistry chemical and spectrographic analysis was used [10]. To study physical properties of obtained alloys durometric analysis was used (by means of microhardness tester PMT-3). The phase composition of alloys was determined by X-ray microanalysis method by means of JSM-6490 microscope, as well as by means of optical microscope "Neophot-21". X-ray phase analysis was performed by means of diffractometer DRON-3 in monochromatic Fe-Kα radiation for voltage U=35 kV and anode current I=14 mA. The types and temperatures of phase transformations were determined by differential thermal analysis method using a derivatograph. The precision of measurement is of ±5. The study of hardening process was carried out for the case of iron-carbon specimens, part of which was preannealed at the temperatures of 1123-1173 K. Degree of superheat while melting of alloys specimens is no more than 30 K above liquidus curve. Heating and cooling rate is of 30-40 K/min.

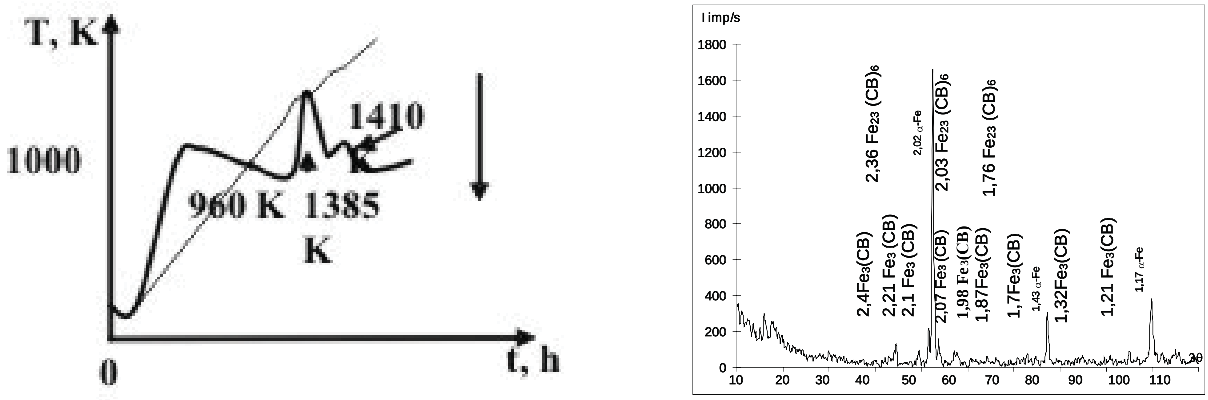
Results and discussion

Fig. 1 presents the microstructure of initial Fe-B-C system alloy.

The morphology of specimen includes primary light-coloured dendrites of $Fe_3(CB)$ phase and plate-like eutectics γ-Fe+$Fe_3(CB)$ (Fig. 1, a). According to results of X-ray structure analysis in diffractograms of alloy there are curves of cubic boron carbide $Fe_{23}(CB)_6$, but in the process of microstructure investigation this phase is not revealed (Fig. 2, b). The thermogram of such an alloy is shown in Fig. 2, a. The thermal effect, which was observed at the temperatures of 1408-1410 K, corresponds to precipitate of dendrites of boron cementite $Fe_3(CB)$. The eutectic constituent γ-Fe+$Fe_3(CB)$ is formed within the temperature interval of 1401-1385 K. At the temperature of 960 K the formation of austenite takes place.

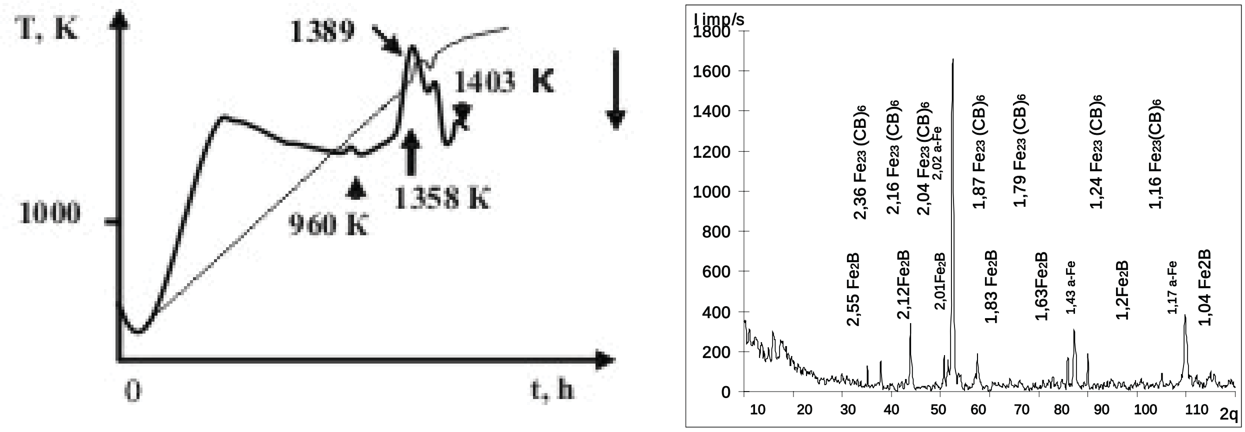
In Fig. 1, b there is presented the microstructure of alloy, which after melting had been preannealed at the temperature of 1170 K for an hour, and then had been heated up to temperature 30 K above liquidus, and then was cooled with a rate 40 K/min. The X-ray structure analysis of this alloy shows presence of the curves, peculiar to boride Fe_2B, boron carbide $Fe_{23}(CB)_6$ and iron α-solution, in diffractograms of alloy (Fig. 3, b). Microstructure of alloy consists of primary borides Fe_2B, which are situated inside the large edged crystals of $Fe_{23}(CB)_6$ phase and finely-divided eutectics γ-Fe+$Fe_{23}(CB)_6$ with a core morphology (Fig. 1, b, c). The thermogram of this alloy is shown in Fig. 3, a.

The precipitates of primary borides take place



a *b*

Fig. 2. Fe-B-C system alloy with boron content of 2,95 % (w.), carbon content of 2,3 % (w.) without preannealing: a) differential thermogram, b) diffractogram



a *b*

Fig. 3. Fe-B-C system alloy with boron content of 2,95 % (w.), carbon content of 2,3 % (w.) after preannealing: a) differential thermogram, b) diffractogram.

within the temperature interval of 1403-1358 K. At the temperature of 1358 K the peritectic dissolution of Fe_2B boride and formation of boron carbide $Fe_{23}(CB)_6$, which takes place within the temperature interval of 1358-1389 K, begins. At the temperature of 1389 K the four-phase transformation $L+Fe_2B \rightarrow Fe_{23}(CB)_6+\gamma$-Fe occurs. As a result of peritectic dissolution of Fe_2B phase the eutectic constituent $Fe_{23}(CB)_6+\gamma$-Fe with fine differentiation is forming (Fig. 1, c). As ground of this one can considered the occurrence of precipitates of Fe_2B phase crystals not only inside the crystals of $Fe_{23}(CB)_6$ phase, but also in surroundings of eutectics $Fe_{23}(CB)_6+\gamma$-Fe. In alloys with boron weight content of 2,4-1,95 % and carbon content of 2-2,4 % without pretreatment in the process of melting and crystallization primary dendrites γ-Fe and plate-like eutectics γ-Fe+Fe_3(CB) are formed. After preannealing in alloys with boron content of 2,4-1,95 % and carbon content of 2-2,4 % at the temperature of 1389 K the eutectic structure with a core morphology $Fe_{23}(CB)_6+\gamma$-Fe is forming. The formation of structures, which include the precipitates of $Fe_{23}(CB)_6$ phase, is associated with their previous formation in a solid state while preannealing. According to results of Ref. [9] the formation of $Fe_{23}(CB)_6$ phase in the process of annealing is described by reaction γ-Fe+ $Fe_3(CB) \rightarrow Fe_{23}(CB)_6$ and occurs on interphase boundaries of eutectics γ-Fe+ Fe_3(CB). The analysis of obtained results enables to suppose, that postheating up to melting point and short-term holding at the temperature 30 K above liquidus is followed by formation of complex aggregates, close in composition to $Fe_{23}(CB)_6$ phase composition, in melt. In such a case the preparation of the rest of melt regions with boron atoms takes place. The aftercooling leads to precipitate of primary crystals of Fe_2B boride and $Fe_{23}(CB)_6$ phase as resultant of peritectic reaction $L+Fe_2B \rightarrow Fe_{23}(CB)_6$

Conclusions

1. The formation of cubic boron carbide $Fe_{23}(CB)_6$ in Fe-B-C alloy from liquid state is contingent on preheating up to temperatures of its formation in solid state and coming from existence of its stability range in solid state.

2. The formation of $Fe_{23}(CB)_6$ phase occurs on peritectic dissolving of Fe_2B boride, whereas eutectics $Fe_{23}(CB)_6+\gamma$-Fe is formed as a result of four-phase peritectic transformation $L+Fe_2B \rightarrow Fe_{23}(CB)_6+\gamma$-Fe.

1. N. P. Lyakishev, Yu. L. Pliner, S. I. Lappo. Boron-bearing steels and alloys. Moscow: Metallurgy, 1986. –191 p. (in Russian).
2. Yu. B. Kuzma, P. F. Chaban. Boron-bearing binary and ternary systems. Handbook. Moscow: Metallurgy, 1990. –320 p. (in Russian).
3. G. V. Samsonov, T. I. Serebryakova, V. A. Neronov. Borides. //Moscow: Atomizdat. 1999. – 220 p. (in Russian).
4. Stadelmaier H.H., Gregy R.A. // Metall. vol. 5. – P. 412-422, 1963.
5. Koneko J.H., Nichizawa T., Chiba, Nippon Kinzoku Gakkaishi, vol. 30. , 1966. – P. 263-272.
6. Schiirmann, Li Shao-Xiong // Giesserei-forschung, t. 37. №4, 1985. – P. 121-129.
7. Fomichev O. I. , Katkov V. F. Stability range of ternary phase τ in Fe-B-C system // Izv. Vuz. Chernaya metallurgia, №1, 1988. – P. 101-103 (in Russian).
8. Pilyaeva S. B., Bezrukavaya O. G., Butenko V. F. Pecularities of $Fe_{23}(CB)_6$ compound formation in Fe-B-C alloys // Visnyk Dnipropetrovskoho universytetu. Fizyka. Radioelectronika, Issue 4. 1998. – P. 23-26 (in Russian).
9. Spiridonova I. M. , Pilyaeva S. B. , Butenko V. F. Investigation of the phase stability in isothermal annealing // The matter of formation of metastable of alloys structure. Interuniversity collection of research papers. Dnipropetrovsk, 1984. – P. 155-162 (in Russian).
10. S. B. Tverdokhlebova, I. M. Spiridonova, A. M. Bondarenko. Spectrographic analysis of boron-bearing alloys // Zavodskaya laboratoriya. №11, 1990. – P. 46-49 (in Russian).