

SPECIFIC FEATURES OF THE STRUCTURE, FORMED BY SOLID-STATE NITRIDING OF FERROCHROMIUM

ОСОБЕННОСТИ СТРУКТУРЫ, ФОРМИРОВАННОЙ ПРИ АЗОТИРОВАНИИ ФЕРОХРОМА В ТВЕРДОМ СОСТОЯНИИ

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Abstract / Резюме:

This work presents the results from the investigation of a test specimen, obtained by solid-state nitriding of low-carbon ferrochromium.

The sample was nitrided in a chamber under pressure. It was subjected to metallographic and X-ray microanalysis. Results are shown about the specimen structure formed during the diffusion of the elements in its bulk volume.

KEY WORDS: FERROCHROMIUM, DIFFUSION, NITRIDING.

1. Introduction / Увод

The investigations carried out in the Institute of Metal Science of the Bulgarian Academy of Sciences in the field of solid-phase nitriding of low-carbon ferrochromium by gaseous nitrogen show that during the process of nitriding, except for the diffusion in the bulk of the solid material, internal diffusion of chromium and iron in the bulk of the nitrided alloy takes place as well [1, 2]. As a result, in certain local volumes, a proportion is formed between these two elements, which is quite different than that in the initial material [3].

Taking under consideration the above mentioned facts, the task was formulated for studying in more detail the specific features of these processes and acquiring new data concerning the diffusion of the single elements. These data can be used for the nitriding process mathematical description of double alloys, containing one nitride forming metal, as well as for determining the rate of nitride formation [4]. The better understanding of these problems will contribute to intensifying the nitriding process of ferrochromium, which represents the main nitrogen carrier in high nitrogen steel production.

2. Methodology of experiments / Методика на експериментите

The initial composition of the test specimen is 68% of chromium, 0.02% of carbon and the rest component is iron. Prior to being subjected to nitriding, the cast ferrochromium is remelted three times in a vacuum arc furnace for removing the non-metallic inclusions. It is nitrided in a pneumatic vacuum chamber [5] at $T=1150^{\circ}\text{C}$, $P=0.5\text{ MPa}$ in the course of 5 hours. A metallographic section is prepared by polishing and etching with 20% sulphuric acid. The structure of the sample is studied by means of X-ray structural analysis, metallographic analysis and X-ray microanalysis.

3. Results and analysis / Резултати и анализ

The X-ray structural analysis provides the evidence that the predominating phase in the sample is $(\text{Cr,Fe})_2\text{N}$ [2]. The Cr_2N phase is also present.

Then the specimen was subjected to metallographic analysis. The microhardness was measured in numerous points on the sample surface. It is within the range of 750-1100 HV, which is an indication for the inhomogeneity of the structure.

The microstructure of the non-nitrided cast specimen, determined by means of a metallographic microscope on a

larger area, is shown in Fig. 1. Grains of iron solid solution are clearly outlined in the chromium. Fig. 2 shows a photo of nitrided specimen microstructure, obtained by means of a scanning electron microscope in a mode of reflected electrons. The nitride formations, incorporated in the solid solution, are clearly seen in the figure.

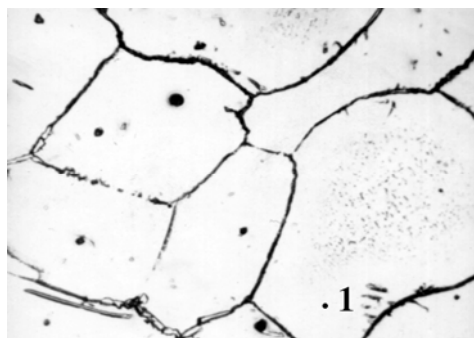


Figure 1. Microstructure of non-nitrided ferrochromium specimen, x500

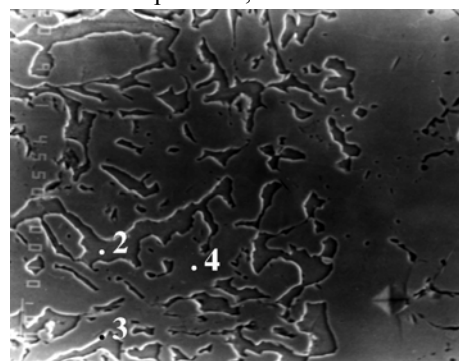


Figure 2. Microstructure of nitrided ferrochromium specimen, x940

In order to determine the Cr/Fe ratio, the samples were investigated using the energy-dispersive spectrometer of the "Superprobe 733" X-ray microanalyzer. This is made in characteristic points of the structure, as shown in Fig. 1 and Fig. 2. Images were obtained in the characteristic X-ray radiation K_{α} and K_{β} , for chromium and iron, respectively.

The spectrum of a non-nitrided specimen is shown in Fig. 3. This relation will be used for comparison further on.

The spectrum, obtained in point 2, which is situated in a formed nitride, is shown in Fig. 4. It is seen in the figure

that the relative iron content is much lower than that presented in Fig. 3. This is due to the fact that chromium atoms were diffused from the surrounding volumes towards the nitride zone and the iron atoms were diffused in the opposite direction. This situation is also confirmed by the spectrum, shown in Fig. 5 (point 3), which is obtained in the bulk of the specimens, in the immediate proximity of the formed nitrides. It is seen that the iron content is higher than the chromium one.

Fig. 6 (point 4) illustrates a case of intermediate value of the Cr/Fe ratio in a local volume of the specimen. It is lower than the respective value in the nitride. In this case, a relatively smaller part of chromium is diffused in the adjacent volumes.

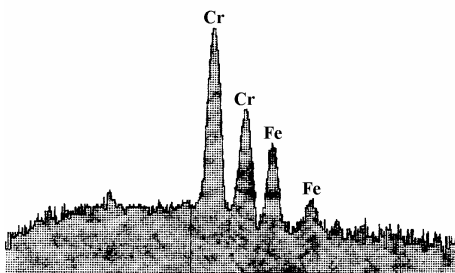


Figure 3. Proportion between chromium and iron in non-nitrided ferrochromium sample (point 1)

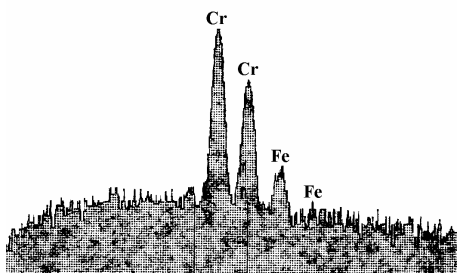


Figure 4. Proportion between chromium and iron in an area of nitrides (point 2)

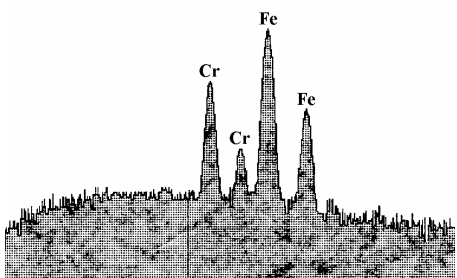


Figure 5. Proportion between chromium and iron in the area around the formed nitrides (point 3)

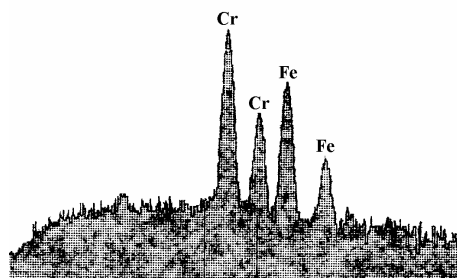


Figure 6. Proportion between chromium and iron in a randomly selected point of the matrix (point 4).

4. Conclusion / Заключение

Investigations were carried out in order to determine some specific regularities in the processes occurring during nitriding of solid-state ferrochromium with gaseous nitrogen. Using the possibilities of X-ray microanalysis, qualitative results are demonstrated, which characterize the diffusion of the single elements in the bulk of the material in the course of the nitride formation process. These results will be used further on in the development of technologies for ferrochromium nitriding, which guarantee high nitrogen content in the obtained product (8-10%) by means of modeling the processes of solid-phase nitriding for varying in structure and volume aggregates.

5. References / Литература

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