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Influence of annealing time and temperature on the Fe_3Al intermetallic alloys microstructure modification

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Abstract

There is an industry interesting in intermetallic alloys in recent years. There are widely possibilities to adopt this kind of materials for structural units. More expensive materials can be replaced by them. A property which limits their wider application is the low plasticity at environment and elevated temperatures. In paper the results of the thermal microstructure modification are shown. To this end, the influence of annealing time and temperature on the intermetallic phase Fe_3Al grain size was investigated. The impact of these factors on micro-hardness was examined as well. It was found that these operations cause the grain size reduction and the micro-hardness decrease.

Keywords: Intermetallic alloys; Fe_3Al; Microstructure;

1. Introduction

There is an industry interesting in intermetallics as structural materials in recent years. They may have a specific applications. Fe-Al intermetallic alloys are materials progressed to produce elements working at elevated temperatures. They have an excellent properties such as very good resistance to oxidation and to action of environments containing sulphur. They are also characterized by a good foundry properties. Fe-Al alloys are considered as a structural materials for reasons of their good mechanical properties [1÷5].

These alloys may be successfully applied in the energy or automotive industry and everywhere, where is a possibility to replace an expensive stainless steel by them. Only what prevent the real Fe-Al intermetallics application, it is a problem with their low plasticity at the environment and elevated temperatures [5÷8].

Modification of the microstructure, especially its fragmentation, gives a chance to change the nature of the plastic deformation mechanisms [9÷11].

2. Investigation procedure

In order to investigate the influence of the annealing time on the Fe_3Al intermetallic phases micro-hardness, following research procedure has been assumed:

- selection of the samples,
- preparation of the samples surfaces,
- microanalysis implementation before annealing,
- micro-hardness ascertainment before annealing,
- heat treatment at the selected temperature and time variants,

- preparation of the samples surfaces after the annealing,
- microanalysis implementation after the annealing,
- micro-hardness ascertainment after the annealing,
- analysis of the results

In the study, four samples obtained from Fe_3Al intermetallic alloy were used. The samples were set to a specially prepared basis, which in terms of the oxidation process does not react with it. Annealing of the sample no 1 was carried at 800°C for 8 h. Samples no 2 and 3 were annealed at 1000°C for respectively 24 and 36 h. Sample no 4 were subjected to nitriding in 600°C for 18 h.

The Fe_3Al samples were placed in the central part of the furnace. Such localization provides to stability of the annealing temperature.

3. Investigated material

Fe_3Al alloy before annealing process is characterized by a coarse grains of the phase structure. The individual grains are about 80µm in diameter (fig. 1.).

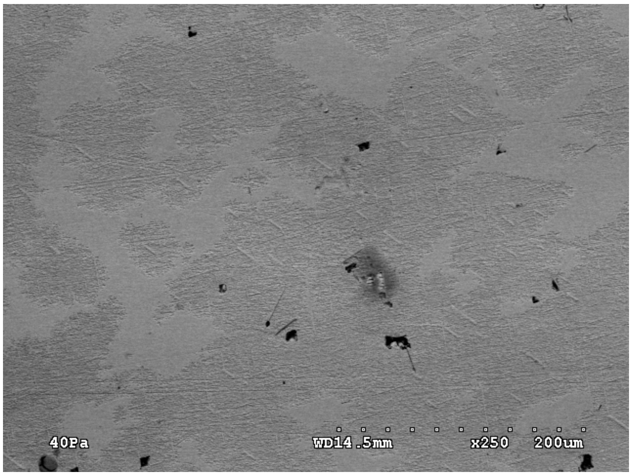

Fig. 1. Fe_3Al alloy structure before annealing process

4. Experimental work

After annealing, samples no 1, 2 and 3 were subjected to the micro-hardness test. Results of the micro-hardness measurements before and after annealing process are shown in table 1.

Table 1: Results of the micro-hardness measurements

	Micro-hardness [µHV 0,1]
1	835
2	865
3	882
1 (800°C, 8 h)	612
2 (1000°C, 24 h)	627
3 (1000°C, 36 h)	519

Samples in initial state have a greater hardness compared to samples after the annealing process. Minimal micro-hardness is characteristic for the sample no 3. Sample no 2 (1000°C, 24 h) has about 17% greater hardness in relation to the sample no 3 (1000°C, 36 h). The greatest decrease in the hardness after the annealing process is characteristic to the sample no 3 - 41%. In the case of the sample no 1 and 2, the difference in hardness is 27%.Temperature and time of heating has a significant impact on the samples hardness.

In the case of the nitrided at 600°C for 18 h sample the micro-hardness test were started from the nitrogenous layer and carried out in distance of 0.3mm to the depth of the sample. At this section 5 micro-hardness measurements have been done. The nitrided sample measurements results are shown on fig. 2.

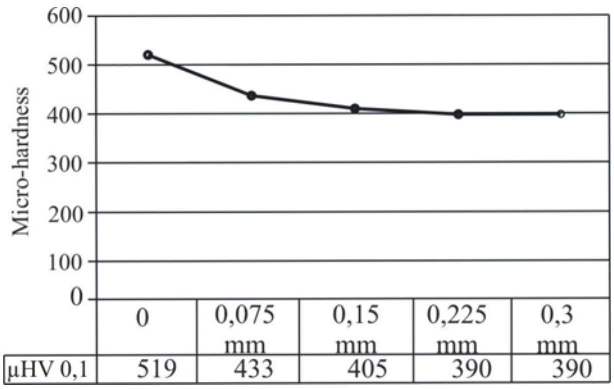

Fig. 2. Changes in micro-hardness depending on the distance

In the case of annealed at 800°C for 8 h sample (sample no 1) the beginning of recrystallisation process was observed. Recrystallised grains are detectable in the vicinity of the main grains boundaries. The grains are about 20 µm in diameter and have a regular shape (fig. 3.).

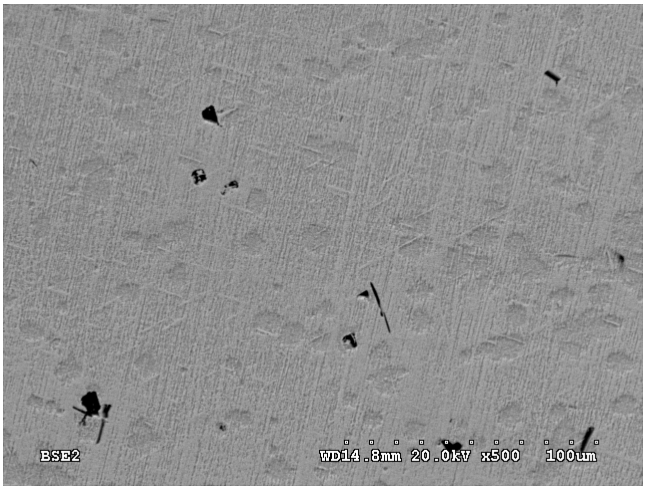

Fig. 3. Structure of the Fe_3Al alloy after annealing at 800°C for 8 h

In the Fe_3Al sample heated at 1000°C and for 24 hours, further progress of the recrystallisation process and the evolution of new grains has been observed (fig. 4.).

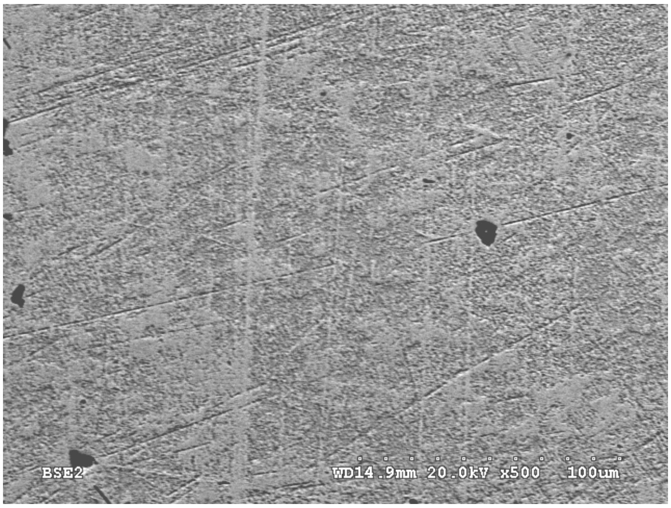

Fig. 4. Structure of the Fe_3Al alloy after annealing at 1000 °C for 24 h

In the case of the annealing time extension to 36 h at 1000°C there is a continuation of the recrystallisation process. The grains boundaries are larger (fig. 5.). Increase in the Fe_3Al alloy grains boundaries causes significantly micro-hardness drop.

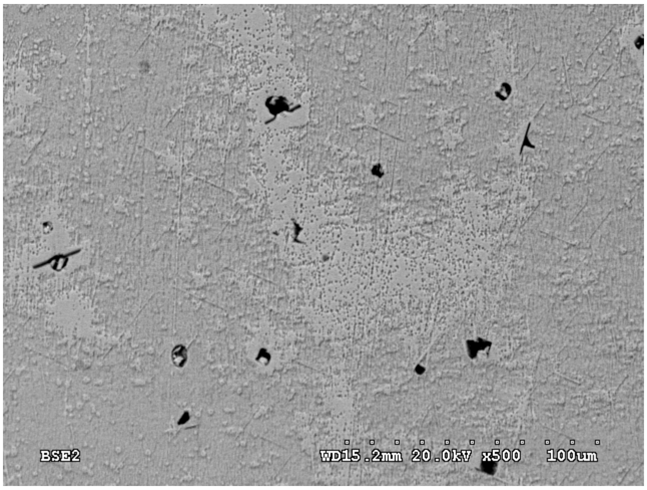

Fig. 5. Structure of the Fe_3Al alloy after annealing at 1000 °C for 36 h

In the case of a nitrided sample at 600 °C for 18 h grains structure has not been changed. Below nitrogenous layer the fine grained structure is visible (fig. 6.).

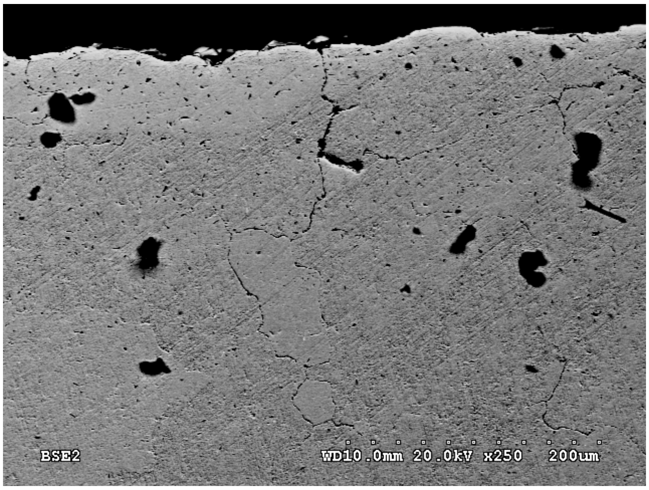

Fig. 6. The structure of the nitrogenous layer after nitriding at 600 °C for 18 h

4. Conclusions

As a result of the studies, following conclusions can be formulated:

1. Fe_3Al sample before annealing process has a coarse grain structure. Individual grain is about 80 μm in diameter.
2. Nitriding process at 600 °C for 18 h increases hardness in the area of nitrogenous layer.
3. There is a beginning of a grains recrystallisation process while annealing at 800 °C for 8 h, the grain size is about 20μm.
4. When annealing at 1000 °C for 24 h the recrystallisation process is increasing, and a growth of a new grains is taking place.

Information obtained as a result of the Fe_3Al alloy investigations can serve as a basis for the designing of heat treatment technology for this group of materials.

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