INFLUENCE OF PLASTIC DEFORMATION ON STRUCTURAL CHARACTERISTICS AND LONG-RANGE ORDER IN Ni_3Al ALLOY

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1. Introduction

The interest in the intermetallic alloy Ni_3Al due to its unique properties is kept up for a long time. Properties of alloy are connected with a high ordering energy. The long-range order remains up to the melting temperature. However, plastic deformation essentially can change a structural state of alloy Ni_3Al [1], decrease the long-range order degree and even can lead to its full destruction.

2. Experimental procedure

In this work the study of structural characteristics of the coarse-crystalline alloy Ni_3Al deformed by cold-rolling at a room temperature is presented.

The X-ray diffraction was used to determine the average internal strain, the crystallite sizes and the average size of antiphase domains based on the Hall-Williamson analysis of peak broadening [2]. The degree of the long-range order was determined from the ratios of the intensities I_{ss} of the superlattice reflections (100) and (110) to the intensities I_f of the fundamental reflections (200) and (220), respectively, with allowance for necessary factors such as the multiplicity factor P, angular factor Φ and structure factor F:

$$\eta^2 = I_{ss}(P\Phi F^2)_f \, / \, I_f(P\Phi F^2)_{ss}$$

The long-range order parameter, the average size of the antiphase domains, the average size of the areas of coherent dispersion, microstresses and parameters of a crystal lattice are measured with the X-ray methods. Change of these characteristics during deformation gives the information necessary for understanding the phenomena, occurring at deformation of alloys, and also mechanisms of deformation-induced disordering.

3. Results and discussion

Experimental study has showed that the initial state of the alloy Ni_3Al was the two-phase (γ'+γ). The reflexes (220), (311) и (222) of the ordered ($\gamma' \rightarrow L1_2$ superstructure) and the disordered ($\gamma \rightarrow A1$ structure) phases overlap each other. The volume fraction of the ordered phase is about 0.75. It is suitable to the binary constitutional diagram of system Ni-Al. The effective long-range order parameter is η=0.86±0.05 whereas the long-range order parameter within of the ordered phase is η=1.00±0.05. During deformation the effective long-range order parameter decreases (fig. 1.a.1). This decrease occurs because of destruction of the long-range order in local places. Fig.1.a.2 shows the change in the long-range order parameter within of the ordered phase. It will be observed it is accompanied with the emergence of the defective disordered phase. The volume fraction of the disordered phase, which appears in the deformed alloy, is shown in fig. 1.b. The phase composition of the deformed material becomes more complex. There are three different phases. The secondary disordered phase occurs besides the initial ordered and disordered phases. It exhibits that the strain-induced order-disorder phase transition is heterogeneous.

During deformation there is the increase of the defects within the material, growth of microstresses, reduction of size of the areas of crystallites and antiphase domains, increase in a crystal lattice parameter. The dependence between the effective long-range order parameter and density of the deformation antiphase boundaries is obtained. It is noticed that full destruction of the long-range order in the alloy Ni_3Al even after deformation ε=0.95 does not occur. It is possibly connected with a high value of the ordering energy of the alloy. The effect of the plastic deformation on the state of this alloy is carried out under the following scheme:

$$A1_{in} + L1_2 \xrightarrow{\varepsilon} A1_{in} + L1_2 + A1_{\text{sec}}$$

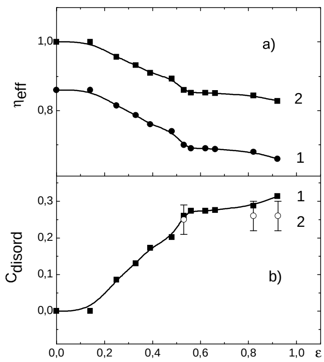

Fig. 1. Dependence: a) 1 - the effective long-range order parameter; 2 - the effective long-range order parameter of ordered phase; b) 1- the volume fraction of disordered phase (experimental); 2 - the volume fraction of disordered phase (calculated) on the degree of strain in the Ni_3Al alloy

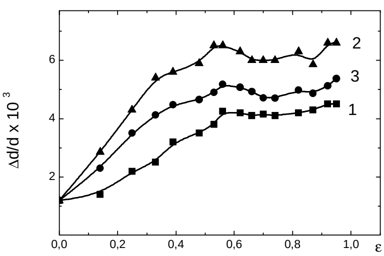

Fig. 2. Dependence of microdistortions Δd/d in the [111] (1), [100] (2) directions and average in all directions (3) on the degree of strain in the Ni_3Al alloy

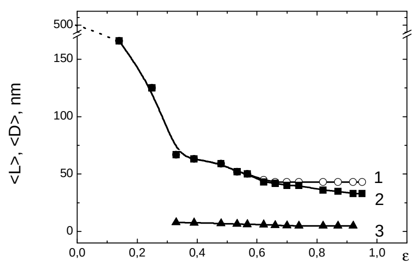

Fig. 3. Dependence of the average size of the crystallites (1), the average size of the antiphase domains (2), the average size of the fine antiphase domains (3) on the degree of strain in the Ni_3Al alloy

A mathematics model of strain-induced destruction of the long-range order in the alloys with $L1_2$ superstructure [2] demonstrated that among different mechanisms of the generation of the antiphase boundaries, such as 1) the accumulation of thermal APBs by means of the intersection of moving dislocations; 2) the formation of APB tubes; 3) the multiplication of superdislocations; 4) the movement of single dislocations; 5) the accumulation APBs at the climb of edge dislocations, only the movement of single dislocations and the formation of APB tubes play the more important role for destruction of the long-range order. However every other mechanism is needed to prepare the action of the most effective mechanisms.

6. References

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