Lamellar precipitation of the influence of the plastic deformation In the Ni-1, 4 at. % In alloy

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Abstract

The particular interest of this work is to study the influence of the plastic deformation on the mode of the precipitation reaction in Ni-1, 4 at. % In alloy. This alloy is characterized by a discontinuous precipitation reaction during an ageing treatment at 600°C; a plastic predeformation does not support this reaction. The technique of analysis used in this respect is the optical microscopy, the SEM, X-ray diffraction.

Key words: precipitation; grain boundary; deformation; dislocation

1. Introduction

Since the discontinuous precipitation discovery [1, 2] in 1930 in the Ag-Cu alloys rich in silver, its comprehension enormously evolved thanks to the scientific and industrial interests because it has a considerable importance in the metal solutions. It modifies the alloys properties sometimes in a favorable direction leading to the breaking load and hardness rises.

Discontinuous precipitation and which consists of the decomposition of a supersaturated solid solution α_0 (mother phase) in interlamellar biphasic structure (α+β) and according to the following reaction: $\alpha_0 \rightarrow \alpha+\beta$

The lamellar structure growths in the α_0 supersaturated solid solution with a reaction front (RF) penetrating and presenting an incoherent phase limit. The important characteristic of discontinuous precipitation respectively lie in the depleted matrix (α) of the precipitated cell, which has the same orientation as grain 1 and the reorientation of the matrix in grain 2, [3, 4].

Many questions of fundamental importance remain not elucidated, because until today we cannot predict the real conditions and necessary so that this reaction can take place. In the same way the principle according to which this reaction spread is not known and exactly in which type of alloy this reaction can take place also [5].

Certain authors have established criteria, for which discontinuous precipitation can take place, but these criteria were checked that they are not general for all alloys. Zener and Hillert [6, 7] think that this reaction initiates with possible maximum speed. Puls and kirkaldy [8] suppose that the entropy production becomes maximal and Cahn [9] postulates a maximum decrease in the free enthalpy time.

Various authors [10-17] have until now examined the discontinuous precipitation mechanisms in the solid solutions rich in Nickel of the Ni-In alloy system contains 1, 4-8 at. % In and noted that the decomposition is carried out according to discontinuous precipitation in fine lamellas with cubic centred faces lattice and whose intermetallic phase is the Ni_3In phase. This initial reaction is accompanied by one second reaction leading the fine structure precipitated to a coalesced structure and always acts of the same phase. These two processes are controlled by the diffusion on the grain boundaries.

According to certain authors [18, 19, 20], in the precipitation reaction, the more probable growth of dislocations plays a dominating role for the nucleation, whose preferential sites of the latter are the large and small angles grain boundaries and other fields rich in dislocations in the matrix. It was accepted that the growth process of the lamellas develops continuously around its vicinity of thermal dislocations, which act like nucleation sites,. The precipitation process can progress in the catalytic way as far as where there is not an interaction between the lamellas growth and the development of dislocations. In the contrary case this process led to the lack of a rigorous discontinuity of this reaction and it is regarded as continuous autocatalytic. In this case the reaction is governed not by the diffusion on the grain boundaries in the reaction front but much more by the diffusion volume. This reaction was found in various alloy systems in which the specific volume of the initial matrix and the reaction product are very different P. Drolet [21] also has shown that the temperature cycle can have as consequence the dislocations development which prevents nucleation on the grain boundaries.

2. Experimental procedures

The material used for this investigation is the Ni-1.4 at % In alloy obtained by vacuum induction melting under inert atmosphere (Argon) from Nickel and Indium very pure. The samples investigated in the experimental study are homogenized for 400 hours at 1045 °C followed by water quench. Their deformation is obtained by cold rolling.

Ageing is carried out at 600°C to cause only the discontinuous precipitation of the intermetallic phase Ni_3 In [15], a part of equilibrium diagram of the Ni-In system.

The metallographic observations were performed using a solution containing 10% of $FeCl_3$ in the ethanol, and the samples were immersed in this solution for 10 to 20 s. The technique of analysis used in this respect is the optical microscopy, the SEM, X-ray diffraction and hardness.

3. Results and discussion

The results obtained after ageing at 600°C of Ni-1, 4 at. % In alloy have shown two possible cases.

3.1. Not deformed alloy

Ageing at 600°C homogenized and quenched in water caused a discontinuous precipitation, characterized by diffusion on the grain boundaries of lamellar precipitate form of fine structure, Fig.1.

3.2. Deformed alloy

A predeformation following to the quenched alloy during ageing at 600°C leads to the appearance of significant number of dislocations inside the grains, Fig.2.a. These structural defects differ from a grain. Grain I shows dislocations of triangular form and in grain II dislocations take in square form, which means that these two adjacent grains have different crystallographic orientations.

In spite of the time aging prolongation at 600°C, Fig.2.b, the discontinuous precipitation reaction is not revealed. A small percentage of precipitation on the grain boundaries could be noted and which will not develop inside the grains. Consequently, the plastic deformation does not support the discontinuous precipitation nucleation, but it supports the structural defects formation (dislocations) during the ageing treatment. In addition, we noted that the fine grains structure, Fig.3.a is favourable to discontinuous precipitation on the grain boundaries (Fig.3.b and Fig.3.c), contrary to a coarse grains structure where the dislocations number is more significant.On the other hand, the observation by scanning electron microscopy (SEM) (fig..4), proved to the lamellar form of the final structure. The analysis by X-ray diffraction, confirmed the two-phase structure ($\alpha + \beta$) (fig.5b) compared to the single phase structure ($\alpha 0$) initial state quenching (Fig.5a). We note that in a recent study [22], on an alloy of the same system but richer in Indium, the discontinuous precipitation reaction is accelerated by a plastic predeformation.

4. Conclusion

The plastic deformation with the precondition of a heat ageing treatment at 600°C of Ni-1, 4 at. % In alloy supports the dislocations formation inside the grains, preventing the discontinuous precipitation reaction. A fine grains structure lead under the same conditions, the appearance of lamellar precipitates in the grain boundaries. A small percentage of precipitation on the grain boundaries could be noted and which will not develop inside the grains.

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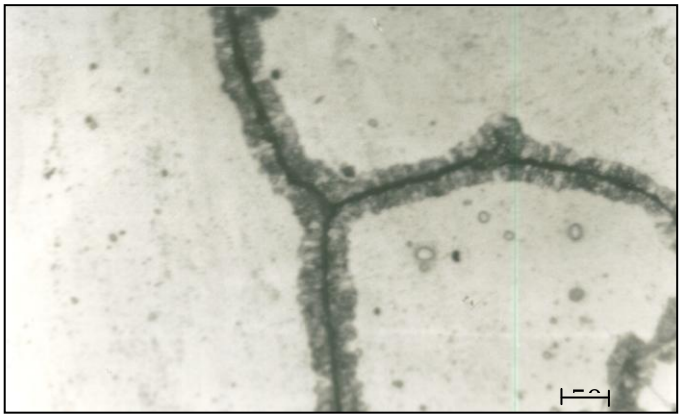

Fig.1. Structural evolution of Ni-1, 4 at % In alloy, after homogenization at 1048°C during 400h, quenched in ice water and annealing at 600°C during 3h

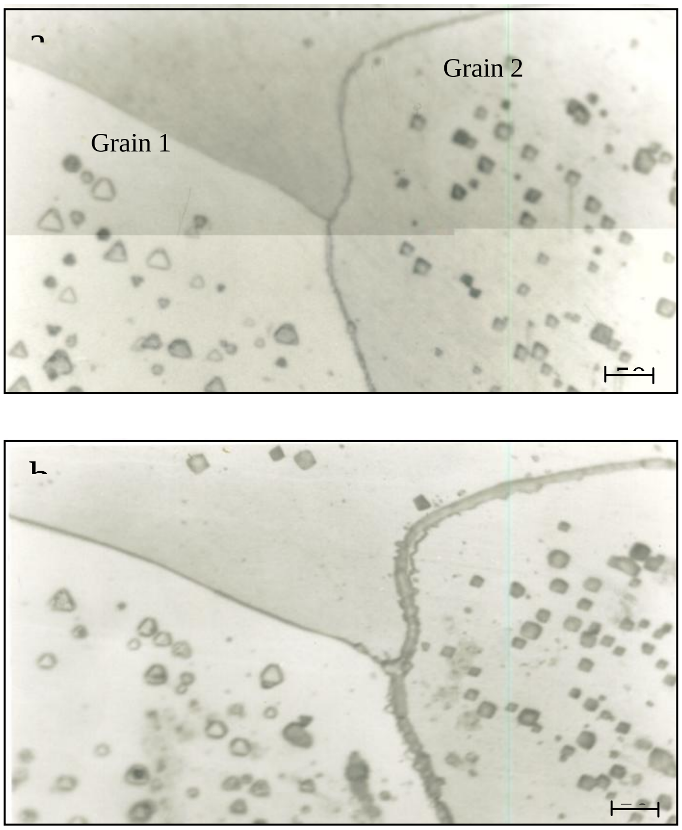

Fig.2. Structural evolution of Ni-1, 4 at % In alloy, after homogenization at 1048°C during 400h, quenched in ice water and deformed by cold rolling 18% and annealing at 600°C during 3h (a) and during 6 h (b)

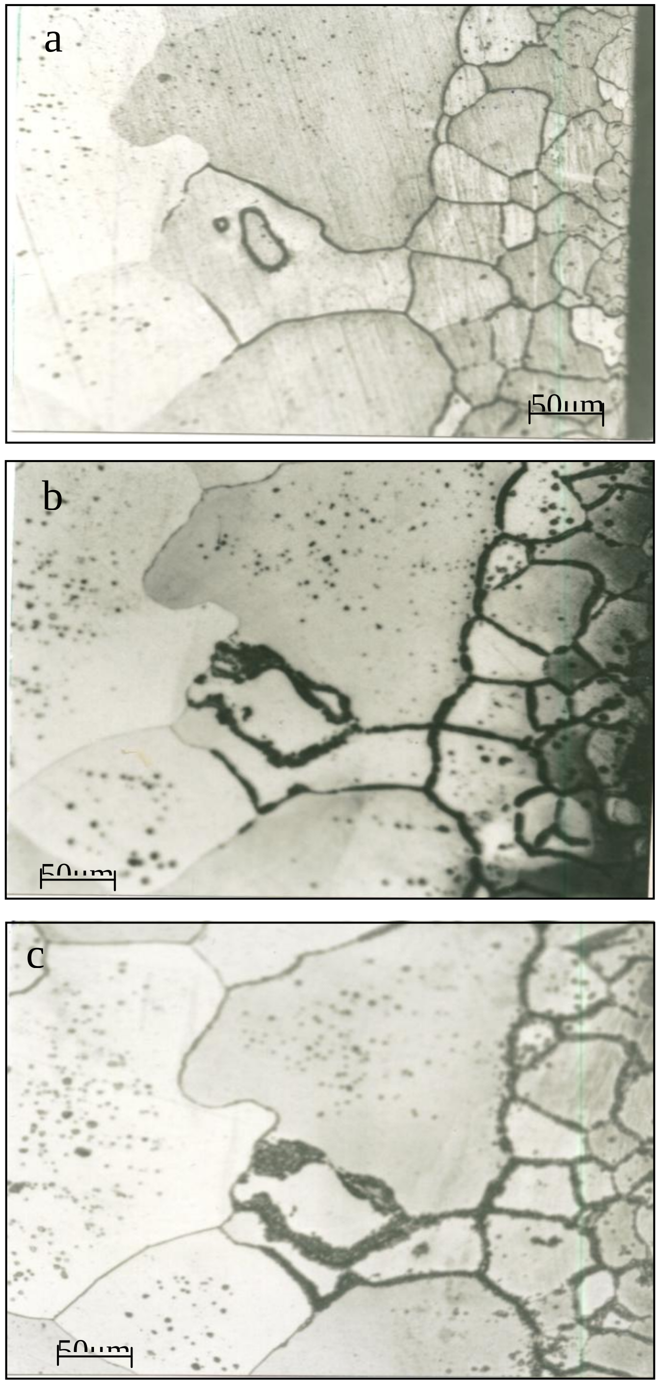

Fig.3. Structural evolution of Ni-1, 4 at % In alloy, after homogenization at 1048°C during 400h, quenched in ice water and deformed by cold rolling 18% and annealing at 600°C during 2h (a), during 3 h (b) and during 6 h (c)

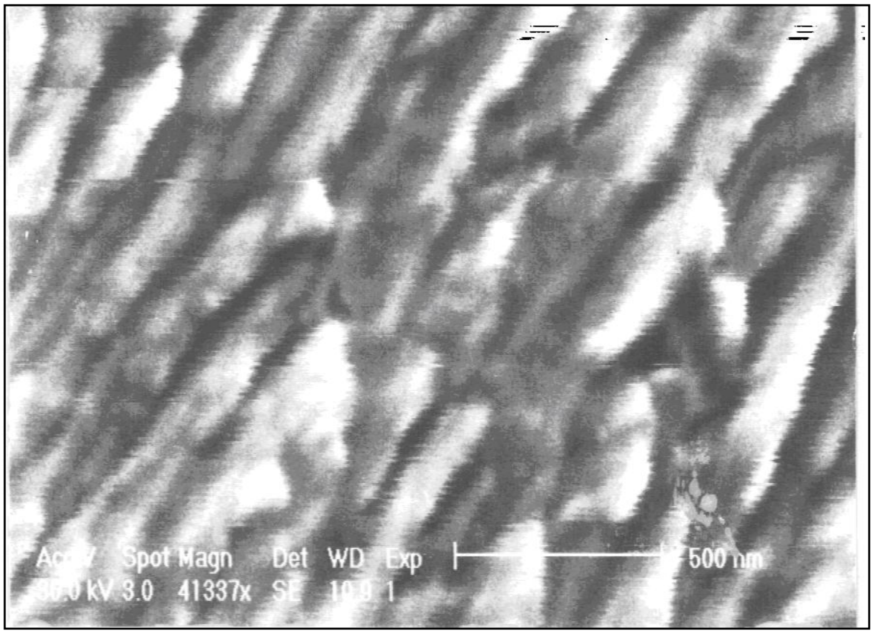

Fig.4. Structural evolution (SEM) of Ni-1, 4 at % In alloy, after homogenization at 1048°C during 400h, quenched in ice water and deformed by cold rolling 18% and annealing at 600°C during 12 h .

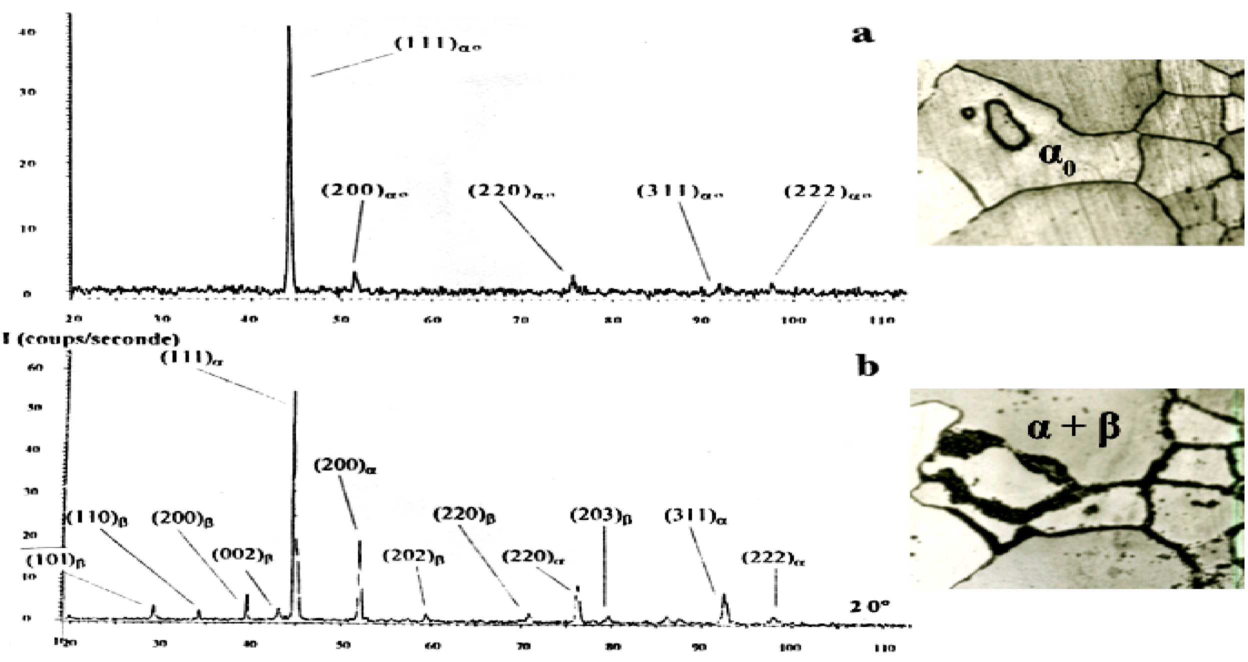

Fig.5. X-ray diffraction of Ni-1, 4 at % In alloy, a) after homogenization at 1048°C during 400h, quenched in ice water and deformed by cold rolling 18% and b) annealing at 600°C during 12 h