HYDROGEN-INDUCED CHANGES IN THE CRYSTALLINE STRUCTURE AND MECHANICAL PROPERTIES OF A Zn-Al EUTECTOID ALLOY RAPIDLY SOLIDIFIED

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ABSTRACT

Ribbon fractions of a zinc-aluminum eutectoid (Zn40.8Al%at.) alloy, obtained by rapid solidification using melt spinning technique, were submitted to a thermo-hydrogenation process by periods of 1, 6, 18, 24, 30, and 48 hours, to 200 °C and 20 atmospheres. Thermo-hydrogenated samples were analyzed by transmission electron microscopy (TEM). Hydrogen-induced changes were produced, such as microstructure refining, development of crystalline defects, microhardness changes and modification of stable crystalline structures to α_R meta-stable phase at room temperature.

1. Introduction

The pearlite is the characteristic microstructure of ZnAl eutectoid alloy and is formed by $\alpha+\eta$ phases alternate lamellaes.[1, 2, 3, 4]

The sudden change from liquid to solid-state of ZnAl alloys, that is it, the rapid solidification, induce formation of: new phases, quasi-crystalline structures, amorphous structures, and crystalline structures and microstructures which are impossible to obtain by conventional solidification.[5] The microstructure of a ZnAl eutectoid alloy solidified rapidly by the melt spinning method is formed by diverse morphologies, among they granular-globular and meta-stable fine pearlite. The ageing process at room temperature induce a coarsening discontinuous reaction and transform the fine pearlite meta-stable α_R phase into coarse pearlite of $\alpha+\eta$ equilibrium phases.[6]

At preceding years, the hydrogen was considered a damaging element; at steels and another alloys is the causing of concept designated hydrogen embrittlement. In the 1970s the possibility of hydrogen use in the materials processing was discovered. The hydrogen may be used as external agent for change microstructure and properties of metals and alloys, providing new effective methods of material treatment.[7]

The treatment of materials with hydrogen is based on the specific characteristics of hydrogen, giving the possibility of a controllable action on materials. This action is reversible in the sense that the hydrogen can be removed from a material even at very low temperatures. Hydrogen action on materials comprises physical, chemical, physical-chemical and mechanical components.[8]

The hydrogen is an element that can to induce amorphization in some alloys and intermetallic materials compound by rare earth metals and transition elements.[9] There are diverse theories on the amorphization causes or modes.[10, 11, 12]

At this work its present the result of thermo-hydrogenation process applied to a ZnAl eutectoid alloy rapidly solidified.

2. Experimental

Ribbon fractions of a ZnAl eutectoid alloy rapidly solidified (Zn40.8 Al % at.) using melt spinning technique, and aged at room temperature, were submitted to thermo-hydrogenation process at 200 °C temperature and 20 atmospheres by periods of 1, 6, 18, 24, 30 and 48 hours into a Pressure Reactor PARR 4842 equipment.

Samples of un-hydrogenated and thermo-hydrogenated ribbon were analyzed by TEM using a JEOL JEM 2010 microscope to 200 kV operation voltage and a JEOL JEM 1200 microscope to 120 kV.

3. Results and Discussion

3.1 Metallography

The microstructure of the un-hydrogenated alloy consist of α (Al-rich) and η (Zn-rich) phases with lamellar-granular morphology, Figs. 1a-b.

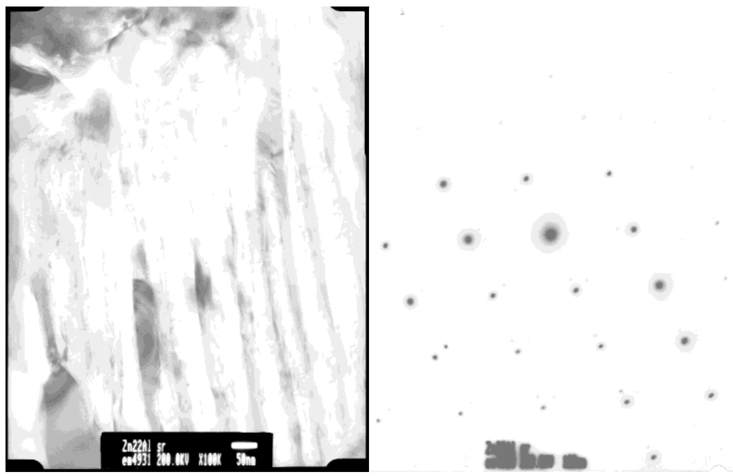
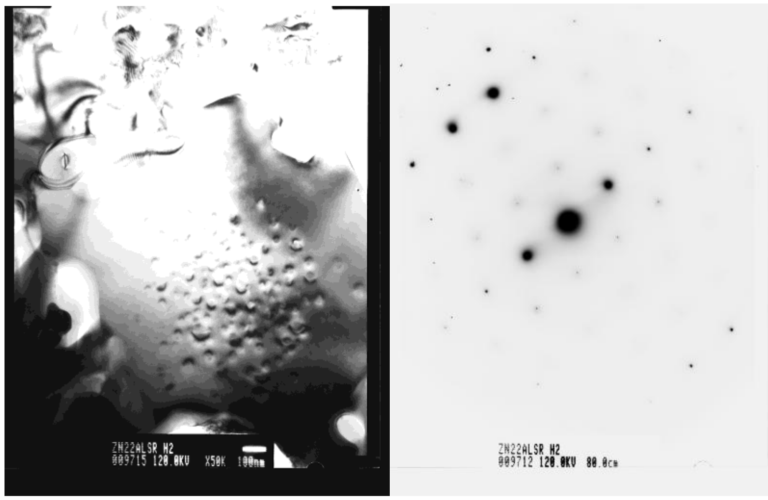


Fig. 1a-b. ZnAl eutectoid alloy un-hydrogenated. Pearlitic microstructure and its p.d.

The thermo-hydrogenation process during 1 and 6 hours affect both α and η phases refining the microstructure and produce fine grains; also generate blisters growth and dislocations Figs. 2a-b. A great quantity of dislocation loops are observed at the alloy thermo-hydrogenated by 18 hours. To temperature and pressure of the thermo-chemical process, the hydrogen gas form small cavities into the grains, for grow, the cavities need vacancies and they its agglomerate at loops by short-range migration, producing near-circular patterns as shown in Fig. 2c. The crystalline defects modify the stable structure to rhombohedral crystalline structure, Fig.2d.

Dislocations are preferential nucleation sites for start thermo-hydrogenation effect. At[13] its mention that exact characteristics of the initial sites of defects crystalline growth is not determined, but at images of experimental results, its observe that affectation start at different sites into the phases; the sites can be vertices formed by dislocations and grain boundaries at which grow vacancies clusters; this positions are suggested because permit hydrogen collection. If the hydrogenation start on grain boundaries discontinuous, its disseminate into the grain through dislocations giving place to dislocation loops. The high pressure of the thermo-hydrogenation process operated as a driving force for hydrogen diffusion through crystalline imperfections throughout volume alloy and for its absorption into the lattices.

The images corresponding to hydrogenated alloys by 24 and 30 hours shows refined zones affected by the thermo-hydrogenation process, which are more notorious at the samples thermo-hydrogenates by 48 hours. The microstructure images of the alloy thermo-hydrogenated 48 hours, show zones of ultrafine-grains, the



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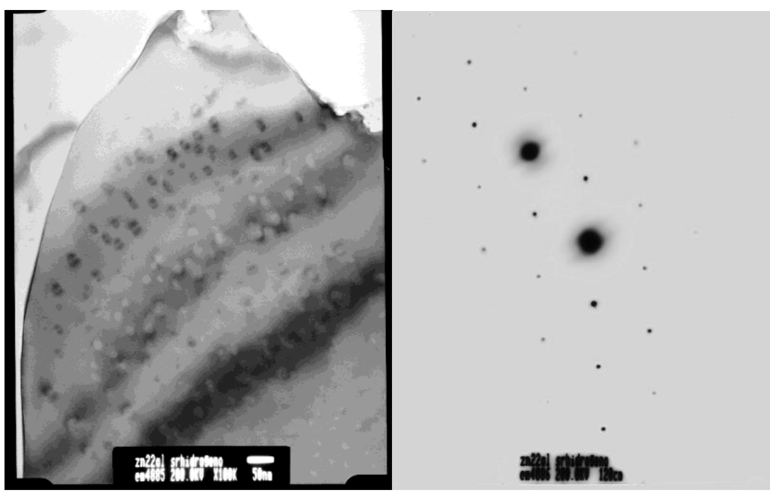

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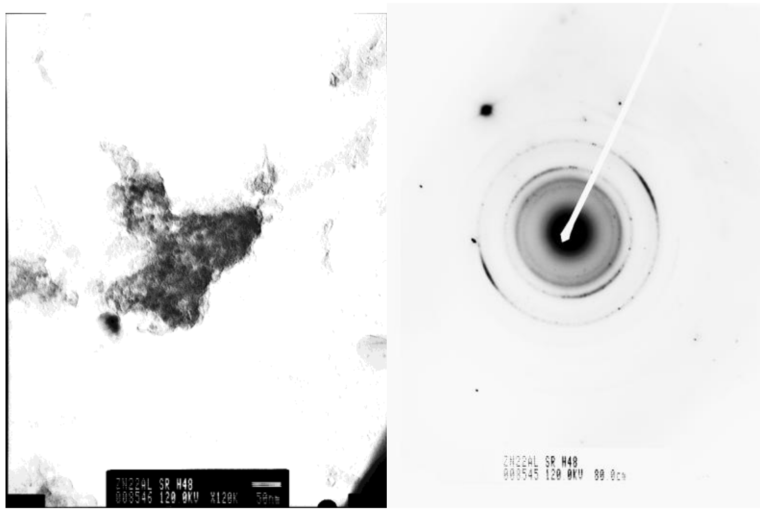

e f

Figures 2. a-b)Blisters in a rhombohedral phase, hydrogenation 6h; c-d) dislocations loops in a rhombohedral phase, hydrogenation 18h ; e-f) Affected microstructure and its p. d., hydrogenation 48h.

hydrogen affect both α and η phases, refining the microstructure which produce an electron diffraction pattern

of points and ring diffuse halo, which indicate that the crystallization diminish, Fig. 2e-f

3.2 Thermogravimetry

The Fig. 3 correspond to a thermo-hydrogenated alloy. On the graph is observed a loss weight among the room temperature and 190 °C interval by a quantity of 0.1609 % or 0.020 mg; the shape curve indicate hydrogen desorption. Also is observed a weight increase between 200 °C and 400 °C, the weight winning was of 0.3233 %, equivalent to 0.040 mg.

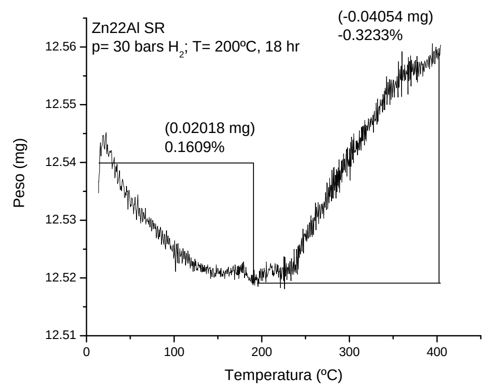

Figure 3. Thermogram of an hydrogenated ZnAl eutectoid alloy.

3.3 Vickers Microhardness

The Vickers micro-hardness (VMh) present a inverse performance to thermo-hydrogenation time among 5 and 24 hours Table 1.

Table 1. Vickers Micro-hardness of ZnAl hydrogenated eutectoid alloy

T hours	0	6	18	24	30
VMh	58	58	51	45	50

The micro-hardness decreasing is due to refining of size grain with the thermo-hydrogenation time.

Conclusions

The thermo-hydrogenation process induce refinement of the microstructure of the Zn-Al eutectoid alloy; this events are realized by break of the grains.

The hydrogen atoms penetrate in interstitial form increasing crystalline lattices volume.

The hydrogen atoms are diffusing by all the bulk alloy, perform internal stress which break the local atomic order causing the crystalline imperfections which modify the f.c.c stable crystalline structure to rhombohedral structure.

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