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Study of Al-Al_3Fe in high frequency magnetic induction fusion Al–Fe

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ABSTRACT

The materials under consideration are binary aluminium-iron alloys (5at.% to 58at.%) elaborated by high frequency magnetic induction fusion. The resulting microstructures have been observed by standard metallography, x-ray powder diffraction and microhardness measurements. Structure of eutectic Al_3Fe phase is described within this article.

Vickers microhardness reaches a maximum of about 900 MPA around 50at.% Fe. This paper reports some structural features of different Al-Fe alloys and highlights, with the help of experimental observations, metastable Al_6Fe in Al-17at.%Fe.

KEYWORDS

Al-Fe;
Rapid solidification;
Al_3Fe;
Microhardness.

INTRODUCTION

Numerous technological applications require the use of intermetallic alloys. New materials can be made relatively easily by changing the stoichiometry of the intermetallic alloys and their crystal structures. Of particular interest are the transition metal aluminides, e.g. FeAl, NiAl, and CoAl, which are resistant to corrosion and oxidation, have interesting magnetic properties[1], and are used as high-temperature structural materials and soft magnetic materials. The partial diagram of the order-disorder transformations in the iron-aluminium alloys was established by x-ray crystallographic analysis by Rimlinger[2]. This diagram defines the fields of existence of the Fe_3Al (DO3) phase and FeAl (B2) phases and provides the critical temperatures of the transitions.

Characterization of solidification microstructures is essential in many applications. However, the composition complexity of most technical alloys makes such analysis quite difficult, in particular for copper-base alloys.

The main purpose of this study is to determine the solidification structure, and phase transformation after melting and casting alloys with different compositions representing the range of iron contents in standard aluminium alloys, for an investigation with X-ray powder diffraction and qualititative microstructure analysis. The hardness of the alloys was also determined.

EXPERIMENTAL

The samples in this study were obtained by a high frequency induction fusion. Powder aluminium, and iron (99.999%) in proportions defined according to the composition aimed of alloy have been used. The total mass of the sample to be elaborated lies between 8g and10g. Cold compaction of mixed powder (Al-Fe) has been achieved to obtain a dense product (60%), intended for high fusion Frequency (HF). The sample thus densified is then placed in a cylindrical alumina crucible (Height: 3cm, Diameter: 16mm), which is introduced into a quartz tube and placed in the coil prior to

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high frequency fusion. After a pumping in primary vacuum, one begins the heating of the sample by steps, with ten minutes maintenance stage towards 600°c and gone up until complete fusion of the alloys. Figure 1.

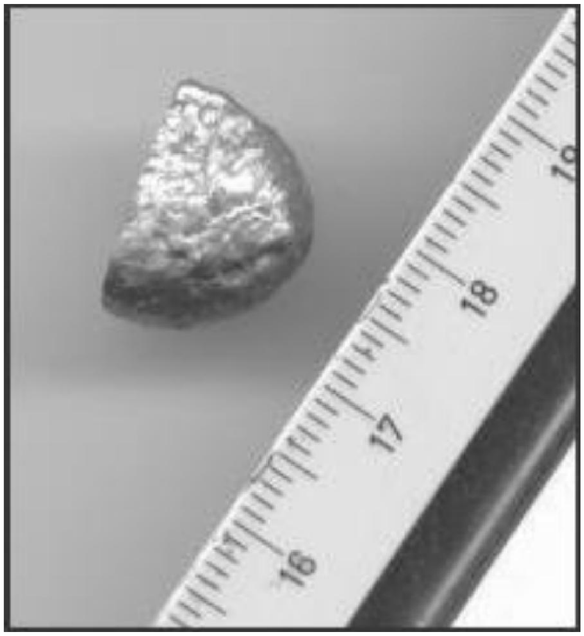

Figure 1 : Shape and size of specimen.

Heat treatment at 500°c during one hour has been achieved under controlled atmosphere. Light microscopy (Philips) has been used for surface observation TABLE 1. X-ray diffraction analysis has been performed using Philips X-ray diffractometer working with copper anticathode (λ = 0.154nm) and covering 110° in 2θ. The structural evolution of various Al-Fe alloys in relation with alloying element composition is indicated in TABLE 1.

RESULTS AND DISCUSSION

Metastable Al_6Fe phase appears beside stable Al_3Fe phase in Al-17.16at. %Fe.

The binary alloys Al-Fe have a considerable interest. Their mechanical properties as well as their oxidation behavior were studied in detail[3,4]. Since the detailed study of the system Al-Fe by Kastner[5], several new results were acquired, other one enters order B_2 and DO_3 as well as variation of concentration of vacancies according to the temperature and composition of the iron rich side of the equilibrium phase diagram.

In the aluminium-2at%iron alloys, Figure 2, and according to the values of the G_L/V ratio[6], a tendency to alignment different from fibers of the eutectic phase is noted. Thus for a high gradient (~ 100-150°C/cm), the alignment of fibers is almost perfect.

The aspect of the Al_3Fe fibers is thus primarily influenced by heat gradient G_L: The rate of solidification plays a secondary role in this case.

The eutectic phase Al_3Fe with monoclinic structure (a=1.549nm,b=0.8nm,c=1.248nm,β =107°71, space group C2/m) appears in the fiber shape parallel with the direction of growth of aluminium. Figure 2.

These fibers are actually rather lengthened plates whose great dimension is parallel to the [111] direction Figure 3.

Habit planes are (100) and (-201) having nearly the same angle with twin plane (001) Figure 2.

These fibers are actually rather lengthened plates

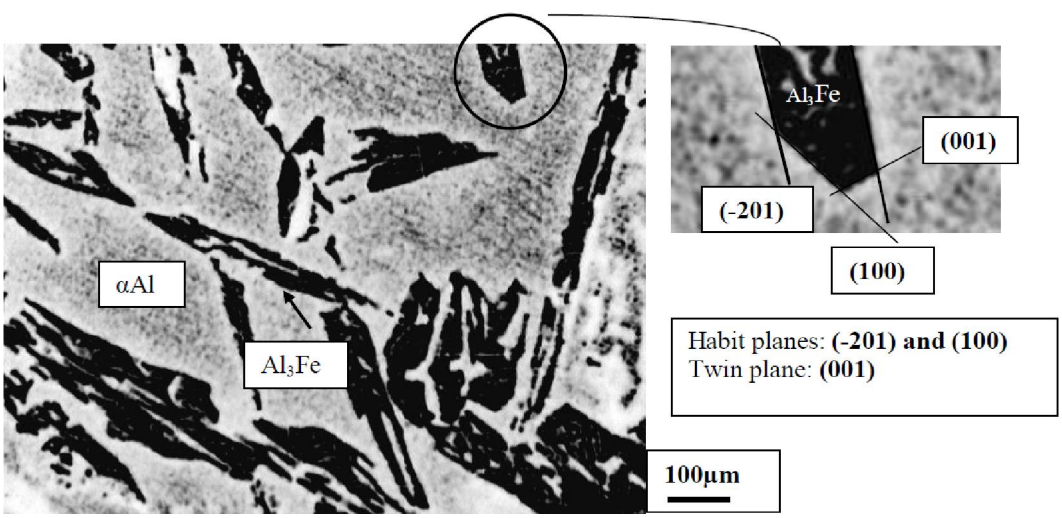

Figure 2 : Optical micrograph (inverted contrast) showing Al_3Fe platelets phase within aluminium matrix.

TABLE 1 : Structural evolution of various Al-Fe alloys in relation with alloying element composition at the as-solidified state and after subsequent heat treatment.

Composition	$Al_{0.95}Fe_{0.05}$	$Al_{0.892}Fe_{0.107}$	$Al_{0.828}Fe_{0.171}$	$Al_{0.674}Fe_{0.325}$	$Al_{0.579}Fe_{0.42}$	$Al_{0.42}Fe_{0.579}$
As-solidified structure	αAl + Al_3Fe	αAl + Al_3Fe	αAl + Al_3Fe+ Al_6Fe	αFe+ Al_2Fe+ Al_5Fe_2	B_2(AlFe) + Al_2Fe	B_2(AlFe) + Al_2Fe
Composition	$Al_{0.95}Fe_{0.05}$	$Al_{0.892}Fe_{0.107}$	$Al_{0.828}Fe_{0.171}$	$Al_{0.674}Fe_{0.325}$	$Al_{0.579}Fe_{0.42}$	$Al_{0.42}Fe_{0.579}$
Annealed structure	αAl + Al_3Fe	αAl + Al_3Fe+Al_2Fe	αAl + Al_3Fe+ Al_5Fe_2	αFe + Al_2Fe+ Al_5Fe_2	B_2(AlFe) + Al_2Fe	B_2(AlFe) + Al_2Fe

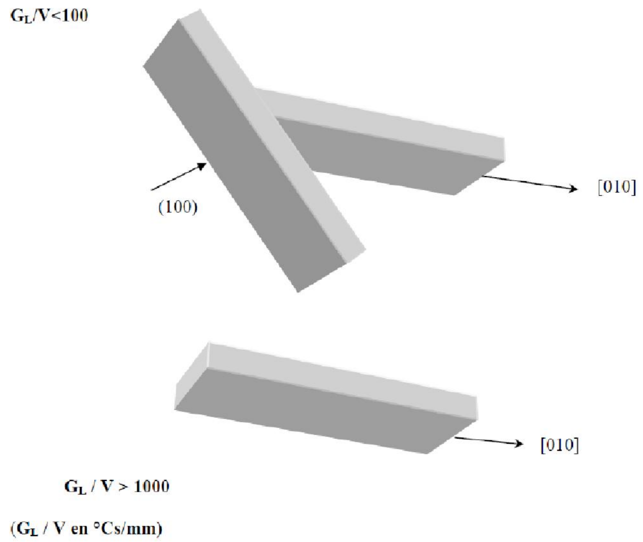

Figure 3 : Schematic Al_3Fe phase platelets orientation.

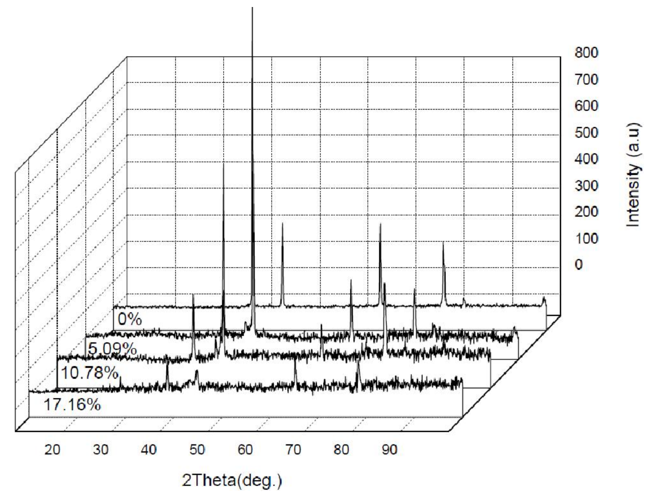

Figure 4 : X-ray diffraction pattern of various As-solidified Al-Fe alloys.

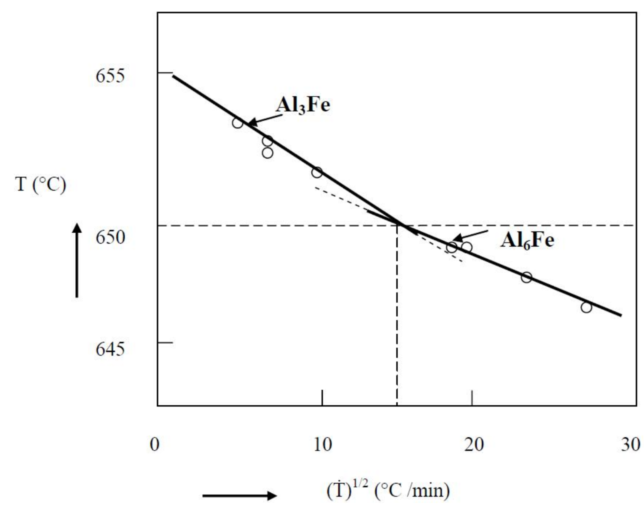

Figure 5 : Temperature versus cooling rate[6].

whose great dimension is parallel to the [010] direction.

For Al-Fe-Si slowly solidified alloys, Iglessis[6] noticed an equilibrium eutectic Al_3Fe phase introducing (100) plane or close to (100) well developed. For higher solidification rate, the surface of Al_3Fe phase decreases on a cross section and other plans of accollement appear as well developed.

Some structural evolution of various Al-Fe alloys in relation with alloying element composition are indicated in Figure 4 and TABLE 1.

The metastable Al_6Fe phase appears beside stable Al_3Fe phase in Al-17.16at. %Fe.

Two factors can determine the morphology and the kind of phases which appears during solidification: The solidification conditions and the chemical composition of the alloy.

Figure 5 represents the eutectic temperature versus the cooling rate for the intermetallic compounds Al_3Fe and Al_6Fe[6]. The later appears for relatively high cooling rates. After subsequent heat treatment Al_6Fe disappears, leaving place to equilibrium Al_5Fe_2 compound.

In Figure 6 one notes that the two curves of variation of the microhardness of the as-solidified and heat treated samples undergo a similar form qualitatively. Between 10% and 30% Fe the microhardness remains almost constant. Beyond 42at.% Fe the value of microhardness will begin increasing. We note an S shaped curve for as-solidified alloys similar to that established for Al-Cu alloys elaborated by high frequency induction fusion[7].

Let us note that for Al-Fe deposits[8], the intrinsic microhardness of thin films increases according to the

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content of iron from 1300 MPa (pure aluminium) until a maximum in form of plate of 8000 MPa located between 45 and 70 %Fe and follows a decrease to reach that of iron towards 4000MPa.

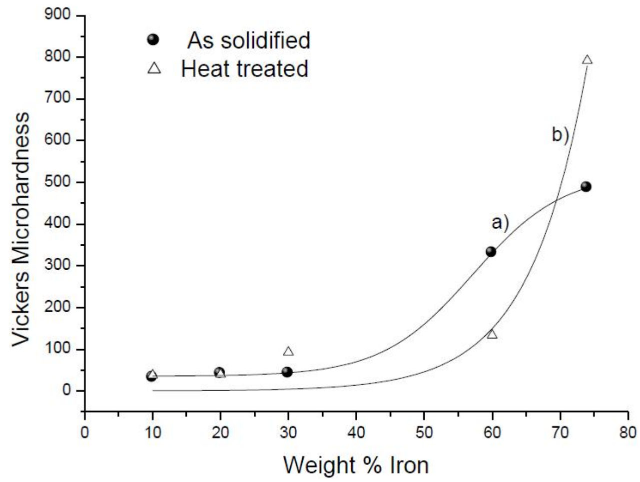

Figure 6 : Microhardness evolution with iron content.

CONCLUSION

As we can gather from our discussion, the main results of the present study are:

The precipitation of a metastable phase as Al_6Fe in the as- solidified alloy is a proof of the efficiency of the process to produce new or not predicted compounds.

The hardness of Al-Fe alloys can be boosted by an increase in the Fe content. The hardness values found in this work are well beyond the values which have, till now, been found. As has been pointed out, the increasing hardness of the alloys as the Fe content increases is explained by the intermetallic Al_3Fe and Al_2Fe phase formation. These phases are found in an eutectic-like structure nearely throughout the whole composition range.

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