Phase Transformation Prediction in Cast Aluminum-Iron-Silicon Alloys

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Abstract the present work describes how metallography analysis correlates with prediction of phase transformations on the base of computational modelling of phase transformation processes in cast aluminum-iron-silicon alloys. Structure components are described for the alloys with different alloying composition. Prediction of phase transformations during structure formation process under cooling should be modelled at first; however, actual structure components distribution will vary.

Keywords aluminum; silicon; metallography; alloys; modelling; casting; phase transformation

1. Introduction

Aluminum-silicon alloys are well-known materials for large usage in various industrial fields [1]. Silicon is added for making an alloy production by casting, and final alloys will have different properties according to their manufacturing technology [2]. In present work, the aluminum-silicon alloys are the subject of investigation; creation of advanced properties of any material may be only made understanding of structural components distribution and its influence on final properties [3]. The present paper demonstrates how modelling made in earlier work [4] correlates with real structural components analysis. All modeled and experimentally made compositions contain iron. Because iron addition allows technologies to produce big amounts of final products at industrial facilities [5].

2. Experimental part

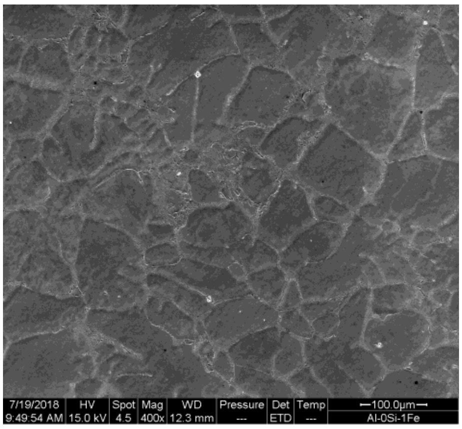
The analyzed compositions are given in table 1. The selection of these compositions is based on the fact that iron improves complete filling of the mold when the alloy is produced by casting technologies [6]. That is why it is necessary to know what phases iron will form during the manufacturing process. The variation of silicon is also required for better understanding of crystallization intervals for every composition.

TABLE I. Analyzed compositions

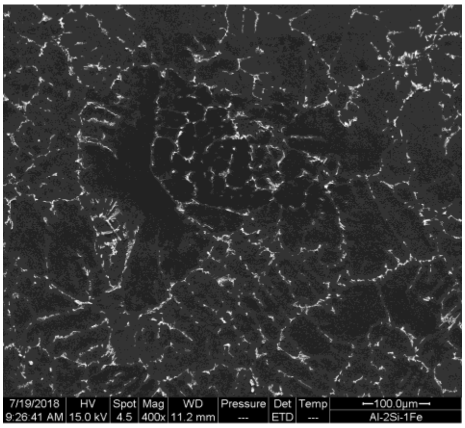
Alloy	Composition		
	Al (%)	***Si (%)***	***Fe (%)***
Alloy 1	99%	0%	1%
Alloy 2	97%	2%	1%
Alloy 3	95%	4%	1%
Alloy 4	93%	6%	1%
Alloy 5	91%	8%	1%
Alloy 6	89%	10%	1%

3. Results and Discussion

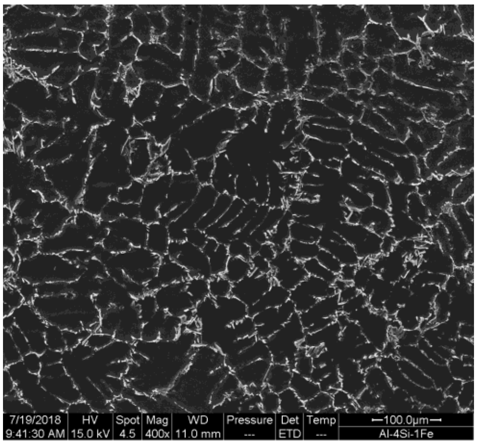
Modelling of different compositions of alloys aluminum-silicon with further obtaining the distribution curves of phases in axes of variation of the silicon concentration were obtained previously [4]. Some parts of phase diagrams including the regions of solid solutions, secondary phases and liquid-solid equilibrium curves were defined [4]. The obtained structures (fig. 1) for the alloys with the compositions Al-0%Si-1%Fe; Al-2%Si-1%Fe and Al-4%Si-1%Fe showed that there were significant changes with increasing the silicon in presence of silicon crystals on the grain boundaries of solid solution The modelled results [4] correspond to the theory [2-3]. In modelled results it was discussed the behavior of iron as an element affecting the stability of iron-containing phases in “liquid + solid = solid” transformations [4]. Obviously, iron is could be a part of solid solution, which was dissolved in a matrix of solid solution during crystallization. The obtained temperature boundaries in paper [4] of each phase showed how the concentration of silicon changed: it was reducing during cooling in all phases. In present results the character of the alloys at room temperature showed that the increasing the amount of silicon mostly results in free silicon phase distribution on the boundaries of grains. Reducing of silicon concentration in every phase influences on final structure components distribution. The major goal of the work is to find how the final properties of experimental alloys correlate with predicted properties as well as what is the use of modern modelling in understanding of real structure formation process.



a)



b)



c)

Fig. 1. Images of: a) Al-0%Si-1%Fe; b) Al-2%Si-1%Fe; c) Al-4%Si-1%Fe

It was discussed [4] more silicon addition into the alloy input resulted in start and finish of crystallization, position of temperature crystallization intervals and positions of the transformations. During crystallization, big impact has cooling rate, because at low cooling rates the liquid might have zones with not equivalent chemical compositions, which finally lead to form phases with different composition of alloying elements like silicon and iron. While crystals of solid solution or chemical phase grow, the content of alloying elements in the liquid phase decreases significantly. Crystals of pure silicon of silicon phase easily distribute on the boundaries of grains of the solid solution. At high cooling rates, the content of silicon will be higher in solid solution and other silicon containing phases. Thus, fixation of high temperature state leads to reduce amount of free silicon, however, if material is heated, diffusion processes and recrystallization will reverse silicon to grain boundaries. It was also suggested that iron-containing phases at high temperature are saturated by silicon.

Thus, modeling gives adequate understanding of a phase composition existence in different temperature regions and expected temperatures of phase transformation areas. However, experimentally obtained alloys might have the unequal content of phases compared to modelled results. Based on simulated diagrams, it is possible to choose an alloy composition, but it is difficult to predict phase distribution in a final structure. Because final structures will be different for the alloys cooled with different cooling rates.

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