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Letter

Al–Ti–C–Sr master alloy—A melt inoculant for simultaneous grain refinement and modification of hypoeutectic Al–Si alloys

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ABSTRACT

Present article is focused on the microstructural features of Al–Ti–C–Sr master alloy, an inoculant for simultaneous grain refinement and modification of hypoeutectic Al–Si alloys. This master alloy is basically a metal matrix composite consisting of TiC and Al_4Sr phases formed in situ in the Al-matrix. TiC particles initiate the refinement of primary α-Al through heterogeneous nucleation in molten hypoeutectic Al–Si alloy, while Al_4Sr phase dissolves in molten Al–7Si alloy enriching the melt with Sr, which eventually leads to modification of eutectic silicon during solidification of the Al–7Si alloy casting. Thus present master alloy serves in both ways, as a grain refiner and a modifier for hypoeutectic Al–Si alloys.

1. Introduction

Melt inoculation of Al–Si alloys has been a common foundry practice for past many decades, in order to achieve grain refinement/modification. Inoculation with the modifier results in modification leading to fine fibrous/globular eutectic silicon, which other wise exist in the form of large plate/needle like morphology [1]. On the other hand, grain refinement of Al–Si alloys has also gained its importance since last decade. Several research works have shown that melt inoculation with various grain refiners like Al–Ti–B, Al–Ti–C master alloys leads to fine equiaxed grain structure, which in turn results in improved mechanical and wear properties [2–7]. Combined grain refinement and modification of hypoeutectic Al–Si alloys has been reported to result in refinement of α-Al and modification of eutectic silicon. In conventional practice, this has been achieved by the addition of modifier and grain refiner master alloys to the molten Al–Si alloys [8–11]. However, it is a difficult task to control the addition levels of individual grain refiner and modifier in actual industrial practice. For this reason, research is being done for synthesizing a master alloy, which can alone result in both grain refinement and modification up on inoculation to molten Al–Si alloy. Sagstad and Bhondus [12] have synthesized master alloy containing Al–Ti–B–Sr, which results in combined grain refinement and modification. In another investigation, it has been reported that mutual poisoning effect of B and Sr, results in the formation of SrB_6 compounds [10,11], which has an adverse effect on the grain refinement and modification. With these short comings of Al–Ti–B–Sr master alloy in view, the present authors have developed Al–Ti–C–Sr master alloy [13,14], which results in simultaneous grain refinement and modification of hypoeutectic Al–Si alloys. Following sections describe the microstructural aspects of the Al–Ti–C–Sr master alloy and its role in achieving simultaneous grain refinement and modification in hypoeutectic Al–Si alloy.

2. Experimental details

Al–Ti–C–Sr master alloy was synthesized by the reaction of molten aluminum with Ti, C and Sr bearing materials, the melt was cast into a preheated graphite mould (detailed process of synthesis of the master alloy has been described elsewhere [13]). Samples collected from the casting have been subjected to metallography followed by SEM, EDS and XRD studies for detailed microstructural analysis of the master alloy prepared.

3. Results and discussion

Typical SEM photomicrographs of the as-cast Al–Ti–C–Sr master alloy have been illustrated in Fig. 1a–c. It can be seen from Fig. 1a and b that coarse intermetallic plates of Al_4Sr (confirmed by EDS spot analysis, Fig. 1d) along with fine TiC particles are formed in α-Al

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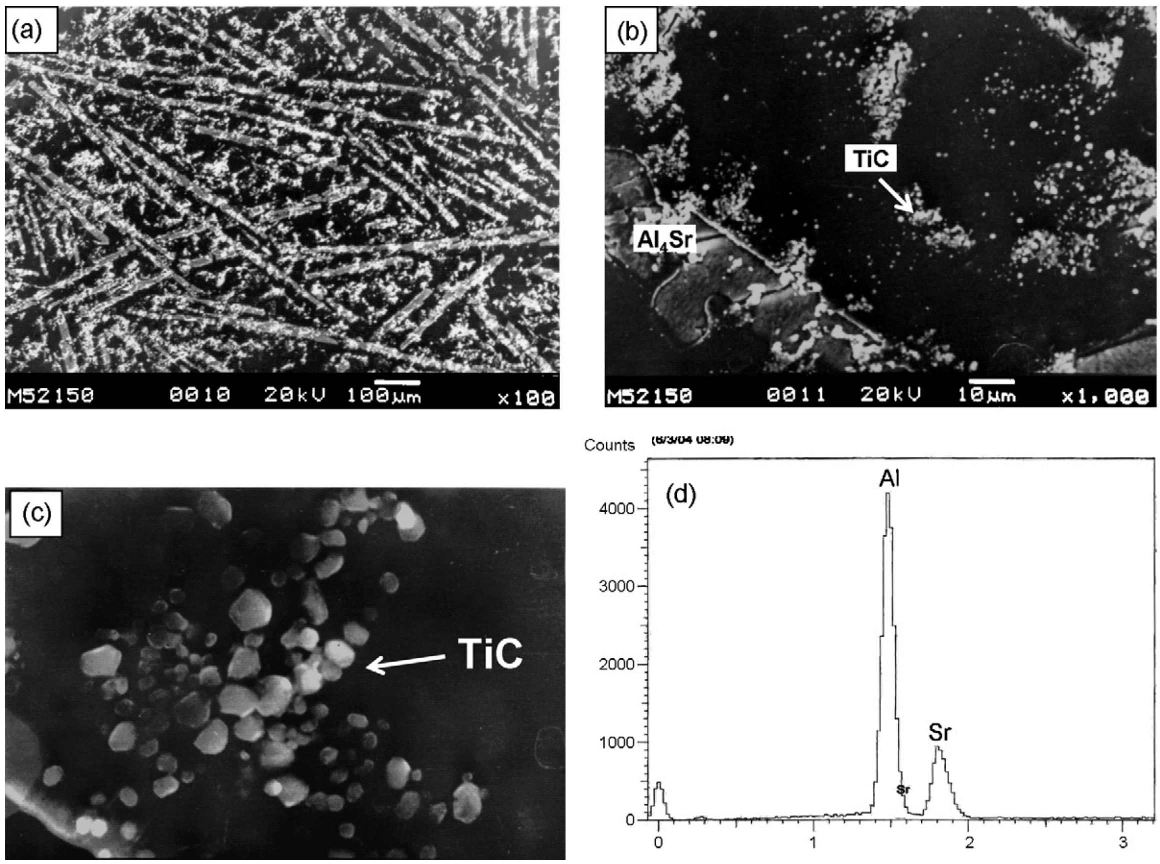

Fig. 1. (a–c) SEM photomicrographs of the as-cast Al–Ti–C–Sr master alloy and (d) EDS spectrum of the Al_4Sr platelet shown in (b).

matrix. In addition Fig. 1c, a higher magnification photomicrograph, reveals the TiC particles found in the α-Al matrix. Fig. 2 describes the XRD pattern obtained from the Al–Ti–C–Sr master alloy. From Fig. 2 it has been confirmed that the phases found are Al_4Sr, TiC and α-Al.

Thus it is understood that TiC and $AlSr_4$ phases are formed in situ in the α-Al matrix. However, it is important to discuss on, how these phases help in grain refinement and modification of hypoeutectic Al–Si alloys. Inoculation of Al–Ti–C–Sr master alloy (in the form of machined turnings) in to molten Al–Si alloy introduces TiC particles and Al_4Sr plates into the melt prior to casting around 720 °C. Al_4Sr plates dissolve in liquid Al–Si alloy, while TiC particles act as heterogeneous nuclei for α-Al dendrites (during solidification of the Al–Si melt). Increase of addition level of Al–Ti–C–Sr master alloy increases the number of α-Al dendrites growing simultaneously and finally followed by eutectic solidification in the inter-dendritic regions, resulting in finer α-Al dendrites. At the same time, Al_4Sr platelets dissolved in the molten Al–7Si alloy raise the Sr level in the melt, which causes modification of eutectic silicon. Thus the combined grain-refinement and modification of hypoeutectic Al–Si alloy is achieved by the Al–Ti–C–Sr master alloy inoculant alone, without any adverse effect. Role of Al–Ti–C–Sr master alloy addition on the microstructure and wear behavior of LM25 alloy (hypoeutectic Al–Si alloy) has been already reported by present authors elsewhere [14].

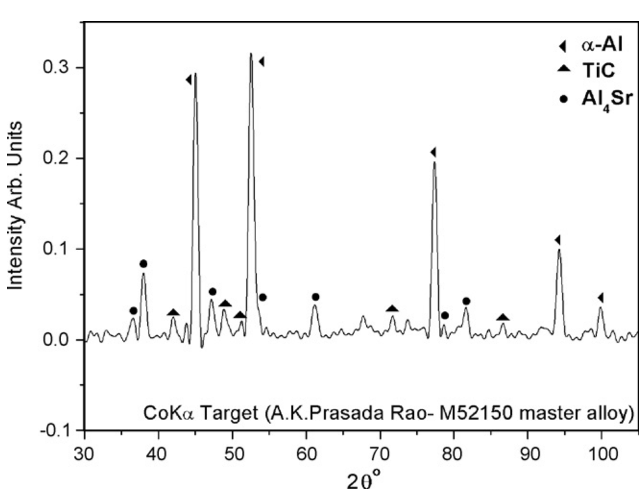

Fig. 2. XRD analysis pattern of the Al–Ti–C–Sr master alloy.

4. Summary

Al–Ti–C–Sr master alloy reported here comprises Al_4Sr and TiC phases in the α-Al matrix. Inoculation of this master alloy supplies these particles/platelets which result in combined grain refinement and modification of hypoeutectic Al–Si alloy effectively.

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