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MODIFINER – A NOVEL MASTER ALLOY FOR COMBINED GRAIN REFINEMENT & MODIFICATION OF Al-7Si ALLOY

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ABSTRACT

A novel master alloy has been synthesized for the first time and characterized in the authors' laboratory. Al-7Si alloy melt has been inoculated with the same in order to obtain combined grain refinement and modification effect. This paper reports the effect of the new master alloy (named as *modifiner*) on the macro and microstructure of Al-7Si alloy.

Keywords: Grain Refinement, Modification, Al-Si alloy, master alloy.

1. INTRODUCTION

Al-Si alloys share a major portion of cast components in automotive, and marine industry. Since last few decades, modification of Al-Si alloys has been a usual foundry practice. Modification results in fine fibrous/ globular eutectic silicon, which other wise exist in the form of large plate/needle like in morphology[1]. Modification also results in improvement in the mechanical properties of the alloys. Grain refinement has also drawn attention of many researchers for last few years. It has been reported that grain refinement leads to fine equiaxed grain structure, which in turn results in improved mechanical and wear properties [2-6]. Modifier and Grain refiners are to be added to the molten Al-Si alloys to get combined grain refinement and modification effects. Many have reported the grain refinement and modification by addition of gain refiner and modifier simultaneously [7-10]. However, it is a difficult task to control the addition levels of individual grain refiner and modifier in actual industrial practice. It has been reported that the combined addition of the Al-Ti-B grain refiner and Al-Sr master alloy results in mutual poisoning of the grain refinement and modification effects [9-10]. Hence it is necessary to search for a new master alloy, which overcomes mutual poisoning effect.

Recently, Sagstad et al. [11] have synthesized and patented a new master alloy containing Al-Ti-B-Sr, which results in combined grain refinement and modification. It was also 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. Present authors have developed a new Al-Ti-C-Sr master alloy, Modifiner, which plays a dual role both as grain refiner as well as modifier at a time. Authors, in the present article discuss the effect of the modifiner on the macro and microstructure of Al-7Si alloy.

2. EXPERIMENTAL DETAILS

An Al-Ti-C-Sr master alloy, "Modifiner", was prepared in the laboratory of the author by reaction of molten aluminium with Ti, C and Sr bearing materials. The authors have already filed a patent application for this master alloy.

Initially, Al-7Si alloy was prepared by melting commercially pure aluminum (99.7%pure) with the Al-20Si master alloy in a graphite crucible in a pit-type resistance furnace at 720^{o}C. The melt has been degassed with commercially available degasser, hexachloroethane. A part of Al-7Si alloy melt has been

poured into a graphite mould of 25mm diameter X 150mm length, and the crucible with the balance melt was replaced back into the furnace. The specimen casting thus obtained has been designated as *0min*, which indicates that it is a casting of un-treated Al-7Si alloy.

In the next step, the calculated amount of modifiner chips have been added to Al-7Si alloy melt, stirred well. After 5min, a part of melt has been poured into the similar graphite mould as in the earlier case. The crucible has been kept back into the furnace with the remaining melt. This specimen casting has been designated as *5min*. Similarly, *30min, 60min* and *120min* specimen castings were obtained. The holding time represents the cumulative holding time from the moment modifiner chips are added. The above experiments were repeated for different addition levels (0.2%, 0.5% and 1.0%) of two modifiners, **M1** (Al-5Ti-2C-3Sr) and **M2** (Al-5Ti-2C-15Sr) synthesized in the laboratory of the authors. The castings obtained from the above experiments were sectioned transversely and prepared for macro and microstructural studies.

3. RESULTS AND DISCUSSION

Figure 1(a), (b) and (c) represent the photomacrographs of Al-7Si alloy treated with 0.2wt%, 0.5wt% and 1.0wt% of **M1** (modifiner), respectively. The numbers 0, 5, 30, 60 and 120 shown in the figures indicate the contact time of the modifiner in the Al-7Si melt. It can be seen that the 0min specimen, shows coarser grains in absence of any treatment. However after a contact time of 5min, significant grain refinement has been observed. It is clear from Fig. 1(a) that on further holding of the melt (30, 60, and 120min), grains got coarsened suggesting fading. It is interesting to note that on increasing the addition level of the modifiner (**M1**) to 0.5% the macrostructure after 5min, 30min and 60min of holding show fine grains (Fig. 1(b)). However, on 120min holding, the specimen casting exhibited coarser grains as compared to that of shorter holding times. It is evident from Fig. 1(b) that on increasing the holding time from 5min onwards, the grains become gradually coarser suggesting the occurrence of fading. On further increase of the addition level to 1.0wt%, macrostructure revealed improved grain refinement. However on longer holding, the macrostructure revealed grain coarsening (Fig. 1(c)). Figure2 (a) and (b) show the SEM photomicrographs of 0.2% of **M1** treated Al-7Si alloy at melt holding of 5min and 120min respectively.

It is clear from the figures that at 5min, little modification has been observed in the eutectic silicon. However in Fig. 2(b), it can be seen that eutectic silicon is acicular in morphology after 120min of melt holding. This obviously is due to the fading of the modifiner on longer holding of the melt. Similar behavior has been observed in the case of Al-7Si alloy inoculated with 0.5% and 1.0% of modifiner, **M1** (Fig. 2(c-f)). However, a comparison of figures 2(a), (c) and (e) indicates that the increase in the addition level of modifiner, improved the modification of the eutectic silicon. Figure 3(a), (b) and (c) represent the photomacrographs of Al-7Si alloy treated with 0.2wt%, 0.5wt% and 1.0wt% of **modifiner**, **M2** respectively. It is interesting to note that at 0.2% and 0.5% of addition, both the modifiners, **M1** (Fig. 1(a-b)) and **M2** (Fig. 2(a-b)) result in similar grain refinement. Interestingly from Fig. 3(c) it can be seen that the photomacrograph of Al-7Si alloy treated with 1.0wt% of **M2** shows that at holding time of 5, 30, 60 and 120min, grains got finer. It is important to note that, at the addition level of 1.0% of **M1**, Al-7Si alloy has shown grain coarsening at 120min holding (Fig. 1(c)). However, for the same addition level of **M2** (Fig. 3(c)), fine equiaxed grain structure has been found at all holding times. This could be due to the higher amount of Sr in the case of **M2** when compared with modifiner, **M1**. This is in contradiction with the earlier reports[9], which claim that Sr does not affect the grain refinement of Al-Si alloys.

Figure4 (a-f) represent SEM photomicrographs of Al-7Si alloy inoculated with 0.2%, 0.5% and 1.0% of modifiner, M2 at different melt holding times. From Fig. 4(a) it can be seen that, in the specimen corresponding to 5min holding time, the morphology of the eutectic silicon is finer than that shown in the Fig. 2(a) for the same addition level of 0.2%. However in Fig. 4(b), it can be seen that eutectic silicon is acicular in morphology after 120min of melt holding. This confirms that the effect of the Sr on longer holding of the melt fades away. Similar behavior has been observed in the case of Al-7Si alloy inoculated with 0.5% and 1.0% of modifiner, M2 (Fig. 4 (c-f)). However, the increase in the addition level of M2, improved the modification of the eutectic silicon.

CONCLUSIONS

i. A novel master alloy, modifiner has been successfully tested on Al-7Si alloy for the first time.
ii. Both grain refinement and modification have been achieved by addition of a single master alloy in one go.
iii. Best results are obtained below 30min of the melt holding of a Modifiner treated Al-7Si alloy.
iv. Modification effect diminishes on longer melting holding.

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FIGURES

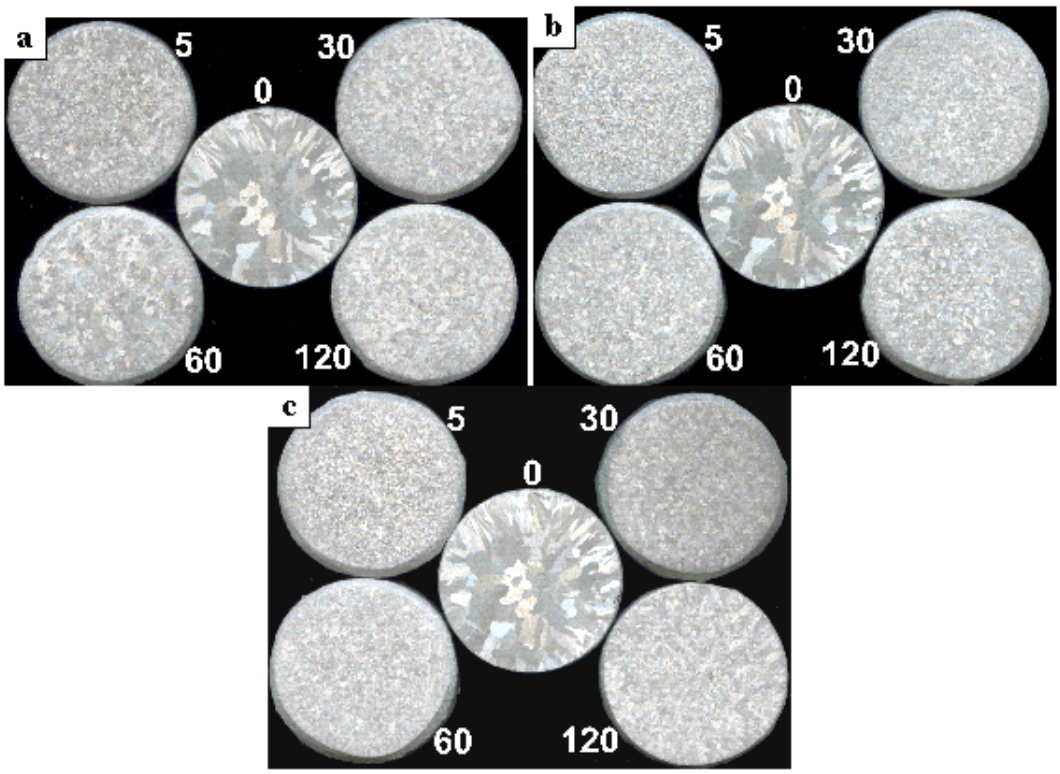

Figure1. Photomacrographs of Al-7Si alloy grain refined and modified with (a) 0.2, (b) 0.5% and 1.0% Modifiner M1 at holding times of 0 to 120min.

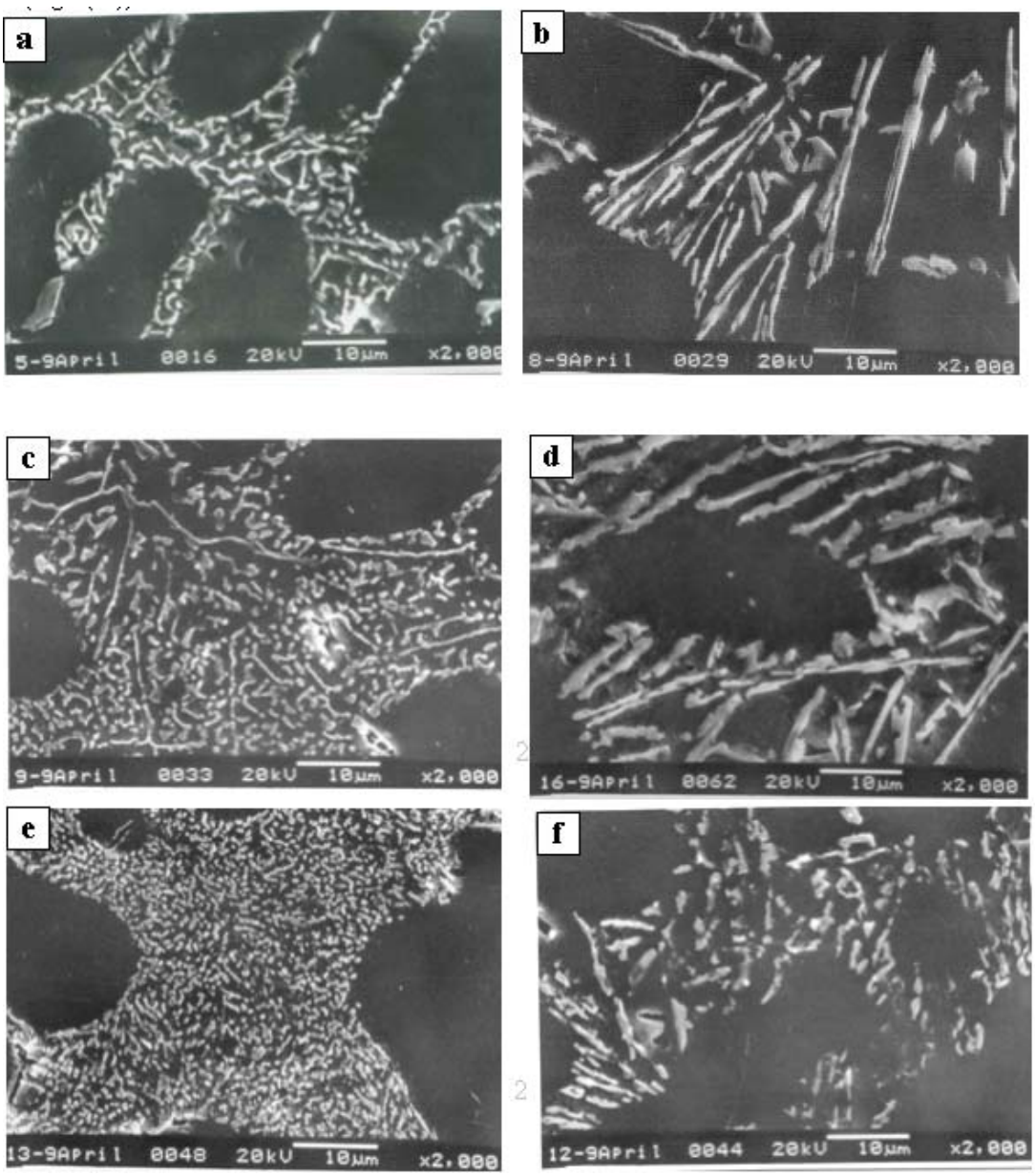

Figure2. SEM Photomicrographs of Al-7Si alloy grain refined and modified with Modifiner-M1 at addition levels and holding time of (a) 0.2%, 5min (b) 0.2%, 120min; (c) 0.5%, 5min, (d) 0.5%, 120min; (e) 1.0%, 5min, (f) 1.0%, 120min.

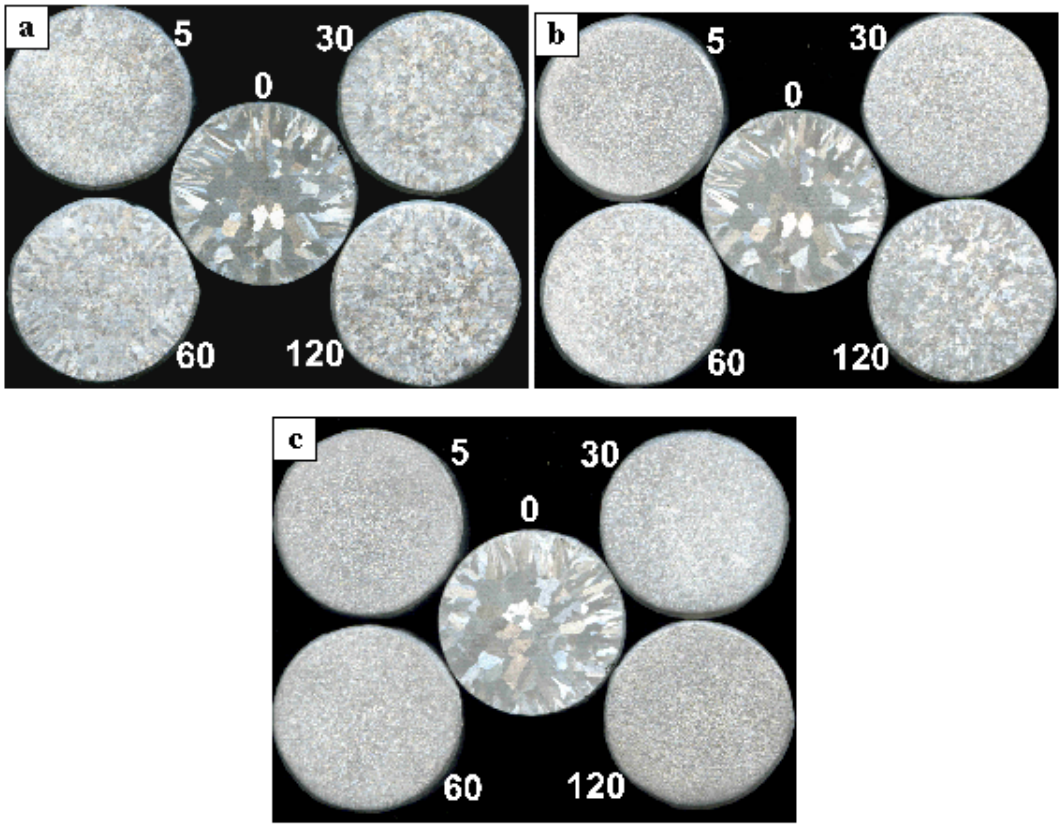

Figure3. Photomacrographs of Al-7Si alloy grain refined and modified with (a) 0.2, (b) 0.5% and 1.0% Modifiner M2 at holding times of 0 to 120min.

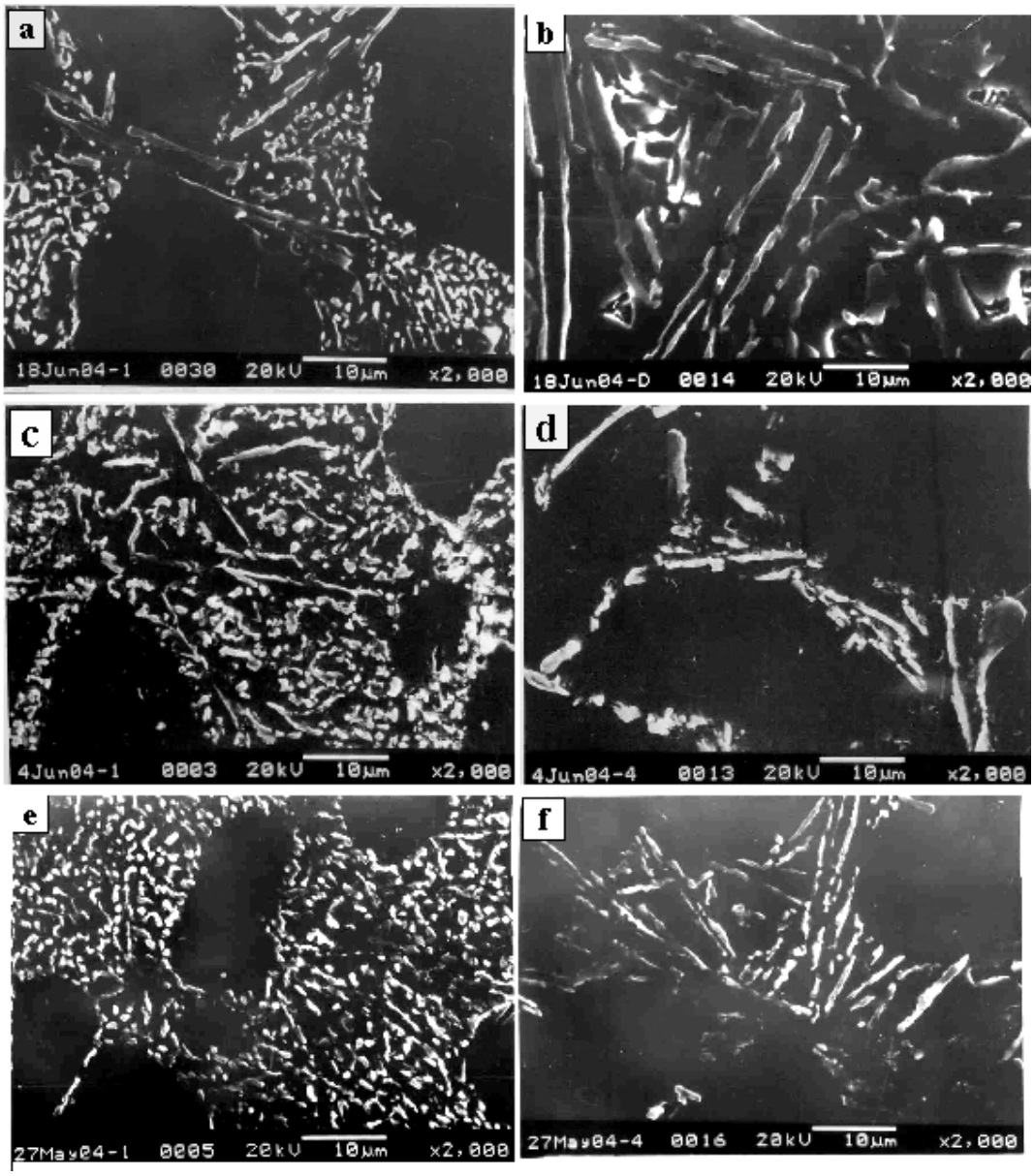

Figure4. SEM Photomicrographs of Al-7Si alloy grain refined and modified with Modifiner-M2 at addition levels and holding time of (a) 0.2%, 5min (b) 0.2%, 120min; (c) 0.5%, 5min, (d) 0.5%, 120min; (e) 1.0%, 5min, (f) 1.0%, 120min.