Review on the Mechanisms of Modification Al-Si alloys

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Abstract

The present paper investigates some mechanisms of modification the eutectic of aluminum-Silicon (Al-Si) alloys. These alloys have been many applications in general industries especially in military, aerospace and automobiles. These alloys in some cases need to modify their properties In particular the wear resistance. This can be overcome by modification the morphology of Si-eutectic. Many mechanisms were suggested in this field. The most common mechanisms are chemical modification and quenching modification. The chemical modification achieved by adding some rare earth elements like sodium (Na), strontium (Sr), and antimony (Sb). Also can be refined the structure of these alloys by using master alloys such as Al-Ti, Al-Ti-B and Al-B. According to restricted growth theory, the impurity induced twinning which reduce the growth. According to the restricted nucleation, the twin plane re-entrant edge (TPRE) Poisoning, which stopped the twin plane. The addition of sodium (Na) in the range of 0.005 to 0.01% modifies the eutectic Si but it has high vapoury and it is difficult to determine its resulting level. Strontium is added in a range of 0.02 to 0.04% but it is ability to oxidation is high as contact with atmosphere.

Key words: Al-Si alloys, Modification of Eutectic, Structure refinement of Al-Si alloys.

Introduction

Aluminum-silicon alloys have an important combination of properties as an alternative to steel, cast iron and titanium-based components in certain applications. These alloys are used as lighter components due to environmental aspects and the development of electrical vehicles represents an opportunity for cast aluminium-silicon alloys as a result of high specific strength, high corrosion resistance, good castability and recyclability. The production cycle effects on the properties of Al-Si alloys. The get the best mechanical properties and good performance many researches were achieved to produce high performance products. The modification of eutectic and primary silicon particles increases the mechanical properties of Al-Si alloys. The modification of these aspects was performed by many ways. The addition of transition elements, alloying elements, and rapid solidification were the most treatments to improve these alloys.

The range of 5 to 23 wt. % Si is the most alloys used in Al-Si system. These alloys have eutectic point at 12.6 wt. % Si at 577 °C [1]. The presence of Si in aluminum alloys increases the molten fluidity, castabilty, good corrosion resistance, tensile strength, and machinability. Different structures; hypoeutectic, eutectic or hypereutectic are formed depending on Si content.

The flake-like Si is changed into a fibrous morphology by a process called modification. This operation (modification) is achieved by several ways; the most common ways are chemical modification and quenching modification. The former can be produced by adding transition elements such as strontium (Sr), sodium (Na) or antimony (Sb) to the melt, these elements are added at very low concentration levels, quenching modification is achieved by a rapid solidification, [2]. Two theories were used to explain the chemical modification effect; the restricted nucleation and the restricted growth theory [3]. According to restricted growth theory, the impurity induced twinning [4]. (Fig. 1a) explain the impairing of the Si growth by poisoning the growing Si ledges and (Fig 1b) explain the twin plane re-entrant edge (TPRE) Poisoning. By poisoning the re-entrant edges, stopping the twin plane re-entrant mechanism. [6]. [5] shows that both mechanisms take place.

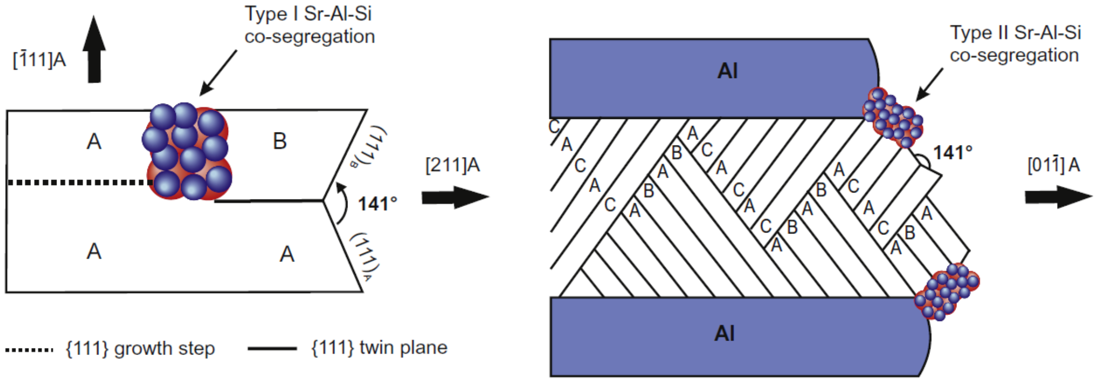

Figure 1: Impurity induced twinning mechanism and b) restricted TPRE growth [6]

The addition of sodium (Na) in the range of 0.005 to 0.01% modifies the eutectic Si but it has high vapourity and it is difficult to determine its resulting level. Strontium is added in a range of 0.02 to 0.04% but it is ability to oxidation is high as contact with atmosphere [7].

Another facility to modification is grain refinement. Grain refinement can be performed by stirring or ultrasonic mixing process [8] or by inoculation with master alloys such as Al-Ti, Al-Ti-B and Al-B master alloys. The effective of inclusions on Al-Si alloys using different kinds of master alloys and the ratio of Titanium (Ti) to boron (B) were widely discussed [9].

Several mechanisms were proposed to explain the grain refinement [10]. Two main theories were suggested by Easton & StJohn [11]: solute theory and nucleant theory. The nucleant theory focused on the specific mechanism happened during the heterogeneous nucleation. The solute theory focused on how the solute elements restrict the growth of imperious at the beginning of nucleation They were going to say both potent nucleant particles and segregation elements are needed for grain refinement to happen[Easton & StJohn, 1999]. This theory was formalized later by StJohn et al. [12]. In some cases when inoculation particles or elements used as nucleants, the grain refinement failed and affect to produce coarse grains. This is called (Si-poisoning) at Al-Si alloys which occurs to some master alloys at Si content exceed 3% [13], [14], [15], [16], [17], [18] as a result of forming silicide compounds [19]. This phenomenon has not been occurs when boron (B) rich master alloy used [20], [21], [22], [23], [24]. But when strontium (Sr) used as modifier element for Al-Si alloys in presence of (B), another compound (SrB6) formed which reduced the ability of modification [25], [26].

How eutectic structures form binary Al-Si alloys

Two phases of eutectic can be formed simultaneously from the liquid of binary Al-Si alloys. These phases may be appearing in a variety of microstructures according to two norms [5]:

Lamellar with fibrous forms as shown in fig. 2a.

Regular with irregular growth as shown in fig. 2b.

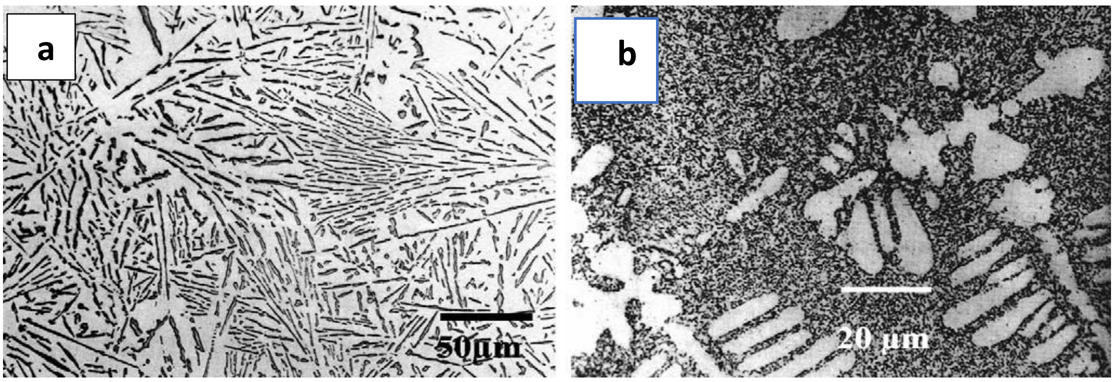

Figure 2: Al-12.6%Si alloy (eutectic phase). a) Low cooling rate, b) high cooling rate [26].

When there are about equal volume fractions of the two phases (α-Al and Si), eutectics of binary alloys exhibit lamellar structures. This type topically appears in slowly cooled foundry alloys when no modifier added. But, if one phase is present in a small volume fraction, this phase tends to be fibrous [26].

Crosley and Mondolfo [27] suggested that the needle-like silicon particles appear in unmodified alloys may be flakes or sheets. In modified alloys tends to grow from the surface of a casting towards the center, while that in unmodified alloys tends to grow randomly within the melt. Li, et al reported that Sr, Na and Eu addition to Al-Si alloy modified the Si eutectic to smaller size [28]. They say that, modification mechanism was as follow (i) adsorption of atoms at twin re-entrant edge, and (ii) segregation across {111}Si growth planes. Fig.3 displays a traditional microstructure of a melt spun high purity Al-5Si alloy without modification operation. It is appear in fig. 3a there are some Si particles are distributed at the grain boundaries.

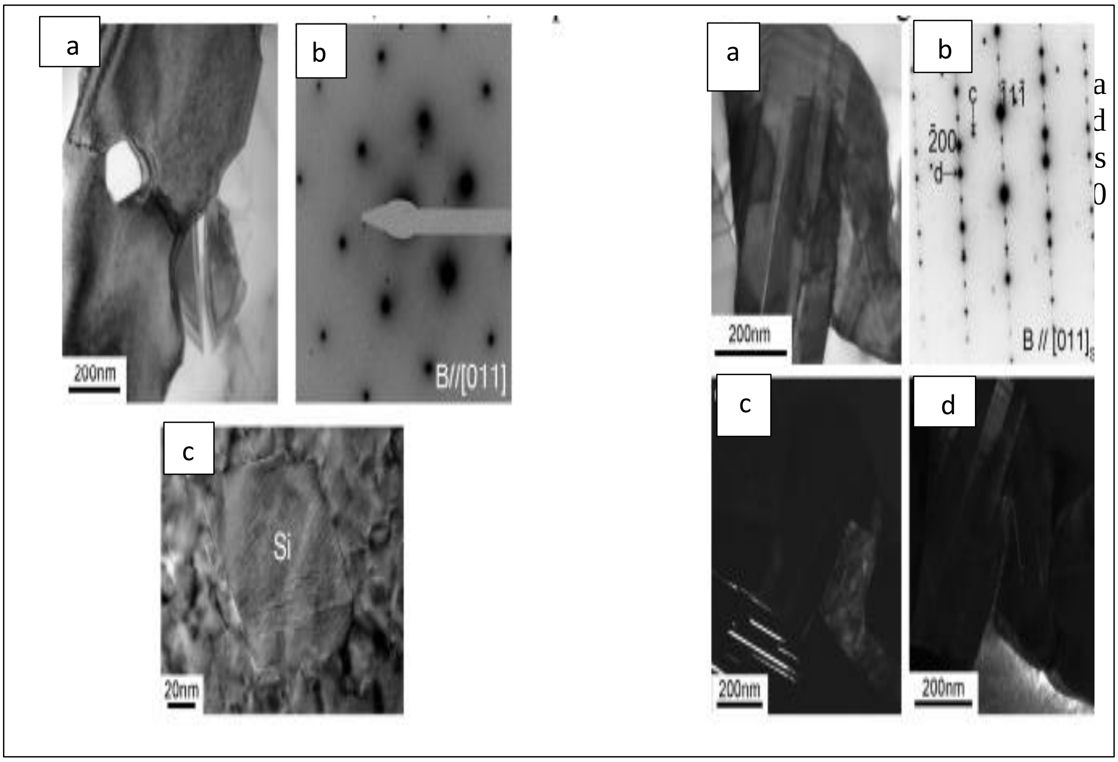

Figure 3: (a) TEM bright field image, (b) Corresponding selected area diffraction Pattern and (c) HRTEM image of Si particles in melt spun Al-5Si alloy [28].

In fig. 3b shows Si particle was tilted to the principal twinning orientation of Si (<011>). (Fig. 3c) shows [011]Si zone axis‹ the Si particle displays to be twinned, although the density of Si twins be low.

Fig.4 explains a multiply twinned Si particle in melt spun Al-5Si alloy with addition of 200 ppm Sr. Fig. 4b explains the selected area diffraction pattern that taken by tilting to the <011>Si zone axis with double diffractions of two variants. Figs. 4c and d show the central dark field images taken from two different diffraction spots corresponding to two different parameters, as appear in Fig. 4b.

Conclusions

Two phases of eutectic can be formed simultaneously from the liquid of binary Al-Si alloys, Lamellar and fibrous. When there are about equal volume fractions of the two phases (α-Al and Si), eutectics of binary alloys exhibit lamellar structures. But, if one phase is present in a small volume fraction, this phase tends to be fibrous

The most common ways for modification the eutectic in Al-Si alloys are chemical modification and quenching modification. The flake like eutectic chanced to fibrous shape by these methods. Each of these methods explained by defined mechanisms. Two theories were used to explain the chemical modification effect; the restricted nucleation and the restricted growth theory. According to restricted growth theory, the impurity induced twinning. Another facility to modification is grain refinement. Grain refinement can be performed by stirring or ultrasonic mixing process or by inoculation with master alloys. Solute theory and nucleant theory were suggested to grain refinement. Formation of silicide compounds causes to Si-poisoning. When strontium (Sr) used as modifier element for Al-Si alloys in presence of (B), another compound (SrB6) formed which reduced the ability of modification.

Sr, Na and Ti addition to Al-Si alloy modified the Si eutectic to smaller size. The modification mechanism was as follow (i) adsorption of atoms at twin re-entrant edge, and (ii) segregation across {111} Si growth planes.

CONFLICT OF INTERESTS.

- There are no conflicts of interest.

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مقالة مراجعة حول اليات تعديل سبائك الالمنيوم– سليكون

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الخلاصة

تبحث هذه المقالة في بعض آليات تعديل االيوتكتك من سبائك الألومنيوم –السيليكون. لقد استخدمت سبائك Al-Si في العديد من التطبيقات في معظم الصناعات وخاصة في المجالات العسكرية والفضائية والسيارات. تحتاج هذه السبائك في بعض الحالات إلى تعديل خصائصها على وجه الخصوص مقاومة التآكل. ويمكن التغلب على هذا عن طريق تعديل مورفولوجية Si-eutectic. تم اقتراح العديد من الآليات في هذا المجال، وأكثر الآليات شيوعًا هي التعديل الكيميائي وتعديل بالتصقيع (معدلات التبريد). التعديل الكيميائي الذي تم تحقيقه بإضافة بعض العناصر الأرضية النادرة (Rare earth) مثل الصوديوم (Na) والسترونتيوم (Sr) والأنتيمون (Sb). كما يمكن تحسين التركيب المجهري لهذه السبائك باستخدام السبائك الرئيسية (Master alloys) مثل Al-Ti، Al-Ti-B وAl-B. وفقا لنظرية عرقلة النمو، فان الشوائب تسبب في تكوين توائم (Twins) مما يقلل النمو. ووفقًا لنظرية عرقلة التخليق، فإن تشويب ال (re-entrant edge) للمستوي التوأم سوف يوقف نموذلك المستوي. إن إضافة الصوديوم (Na) في المدى من 0.005 إلى 0.01٪ يعدل اليوتكتك لكن للصوديوم قابلية عالية للتبخر لذا من الصعب تحديد النسبة المؤثرة فعلا. كذلك يستخدم السترونتيومSr في مدى يتراوح بين 0.02 و 0.04٪، إلا أنقابليته على الأكسدة مرتفعة عند تلامسه مع الجو.

الكلمات الدالة: سبائك الالمنيوم–سليكون، تعديل الايوتكتك، التعديل البنيوي لسبائك الالمنيوم– سليكون