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Effects of Combining Na and Sr additions on Eutectic Modification in Al-Si alloy

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Abstract. Experiments were designed to investigate the effects of strontium and sodium modified on the eutectic silicon for Al-Si alloy. It was found that combining addition of Na and Sr did not appear to cause deleterious interactions of modification, at at the same time, Sr-Na was fairly constant with holding time and without obvious modification fading. Addition of Na-Sr modifier could take effect quickly and decrease incubation period.

1. Introduction

Al-Si alloy is one of the commercial Eutectic aluminum silicon alloys widely applied in automotive engines, because of their good mechanical properties at elevated temperature, excellent wear resistance and low coefficient of expansion[1-3]. However, eutectic Si in untreated exhibits poor ductility even at room temperature[3]. In order to improve mechanical properties, especially fracture toughness and elongation, sodium or strontium is added to Al-Si alloy to transform the eutectic silicon from faceted acicular flakes to a fine fibrous structure[4-7]. It has been reported that the addition of sodium to Al–Si alloys has some drawbacks, such as obvious effect of porosity and sodium fading. On the other hand, the addition of Sr results in increase of hydrogen content and a long incubation[6, 8].Therefore, in present work, attempts were made to investigate any possible interaction by determining the characteristic modification for the eutectic silicon containing Na and Sr. Furthermore, the effect of combining addition of Na and Sr on incubation and modification fading were studied by metallographic analysis.

2. Experimental

Chemical composition of the Al-Si alloy used in this study is shown in table 1 The alloy was melted in a resistance furnace at 750 ℃. After the alloy had melted, the melt was degassed for 15 min using Ar. The modification of the melt were add separately by adding Al-10Sr master alloys, a mixture of Na-salts (two thirds of Na-fluoride and one third of Na-chloride). To investigate the influence of sequential additions, the experiments were divided in two series. In the first series, Sr or Na was first added alone. In the second series, Sr and Na were added simultaneously.The melt was poured at 700℃ into the graphite mould with a cooling rate in the centre of the samples of about 10K/s. Metallographic samples were sectioned horizontally, and were mounted and polished. The ground specimens were then subjected to a final polishing with colloidal silica suspension. An optical microscope (Olympus BX60F5) was used to analyze the microstructures.

For the purpose of illustrating the quantitative modification, the AFS chart known as modification rating was employed in the study. The eutectic silicon morphologies of all samples were categorized into five qualitative levels ranging from coarse needle-like eutectic silicon to fine fibrous eutectic silicon[9]: (1) large plate eutectic Si; (2) plate eutectic Si; (3) longer fibrous eutectic Si; (4) fibrous and needle eutectic Si; (5) fine fibrous eutectic Si.

Table 1. Chemical composition (wt %) of Al-Si alloy

Si	Cu	Mg	Ni	Al
11.5	0.85	0.95	0.85	Bal.

3. Results

3.1Modification with sodium

Figure 1(a) shows the typical microstructure of Al-Si alloy produced by unmodified process. Unmodified alloy reveals coarse plate-like silicon morphology. In contrast, figure (b) clearly shows the fine fibrous morphology of the eutectic Si in a fully modified structure.

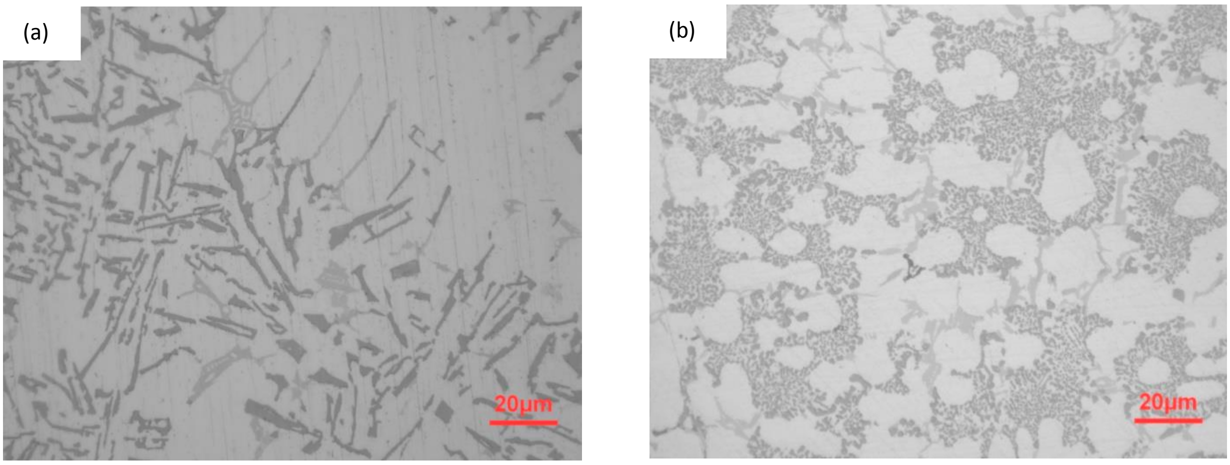

Figure 1. The typical microstructure of Al-Si alloy (a) unmodified alloy;(b) Na-modified (100ppm)

Figure 2 shows modification rating as a function of Na concentration. The results show that there is a strong relationship between Na concentration and modification rating. At the first stage, modification rating increases with the increase of Na concentration, however, it decreases with further increase in Na concentration at the late stage. There is a maxima in the rating–Na curve. The increase in modification rating implies that there is under-modified during initial stage, while the decrease in modification rating suggested that there is over-modification during late stage. The over-modified microstructures of Al-Si alloy, i.e. the over-modification band is obvious infigure 3.

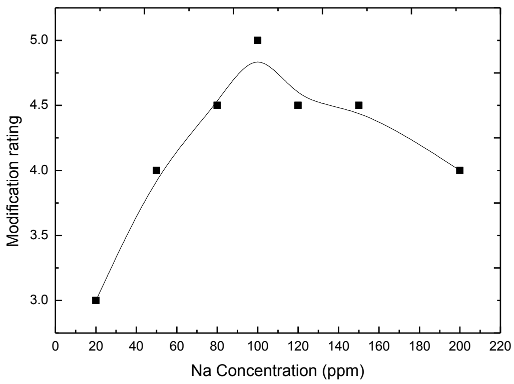

Figure 2. Modification rating a function of Na concentration

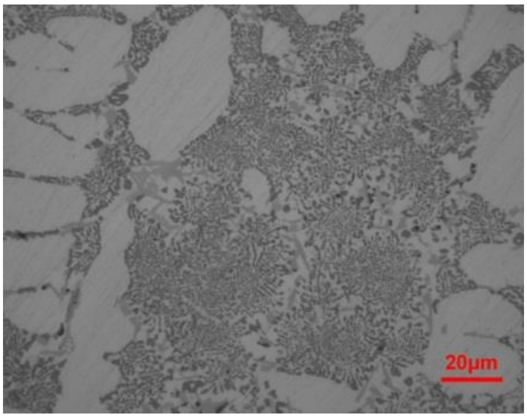

Figure 3. Over-modified structures of Al-Si alloy

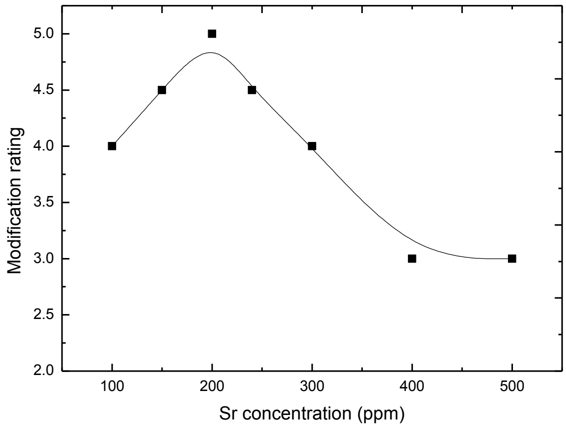

Figure 4. Na concentration a function of holding time

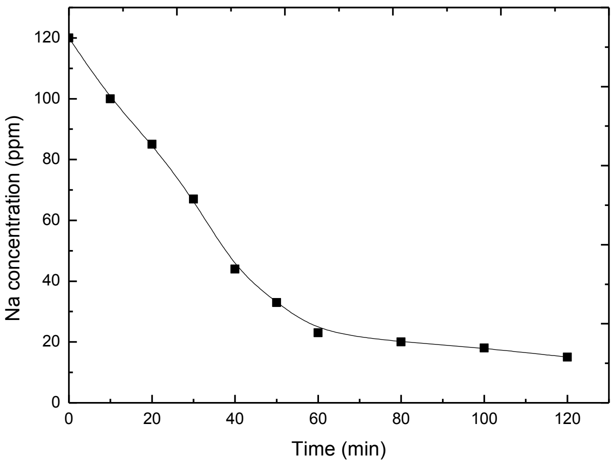

Figure 5. Modification rating a function of Sr concentration

Figure 4 shows Na concentration as a function of holding time with 120ppm Na. Chemical composition analysis indicates that Na concentration decreases with the increase in holding time. A comparison between figure 2 and figure 4 indicates that there is a distinct Na fading. Loss of Na is believed to be responsible for the disappearance of the modification effect during holding time. The lifetime of Na-modified Al-Si alloy is about 20-30 min.

3.2Modification with strontium

Figure 5 shows the correlation between Sr concentration and modification rating. Modification rating first increases and then decreases with increase of Sr concentration. The under-modified structure is observed as at low Sr concentration, which is similar to figure 2. A fibrous or fully modified structure is only obtained when Sr addition is near to 200 ppm. With increase of Sr concentration, the Al_2Si_2Sr intermetallic compound is also observed. Consequently, modification rating is high when Sr concentration takes place at appropriate concentration for Al-Si alloy.

Figure 6 shows Sr concentration as a function of holding time. Sr concentration in the melt decreases slowly with holding time. It is clear that Sr has a slower loss rate than that of Na and a well-modified structure in a long time. A comparison between figure 5 and figure 6 indicats that Sr could has a better modification with increase of holding time, especially for 60 min, or longer.

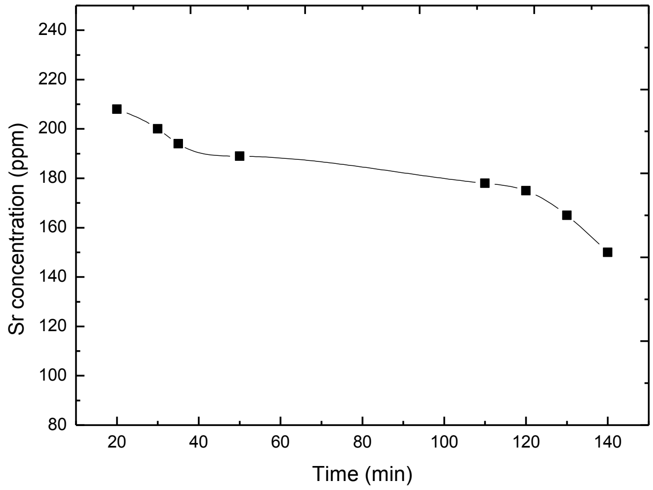

Figure 6. Sr concentration a function

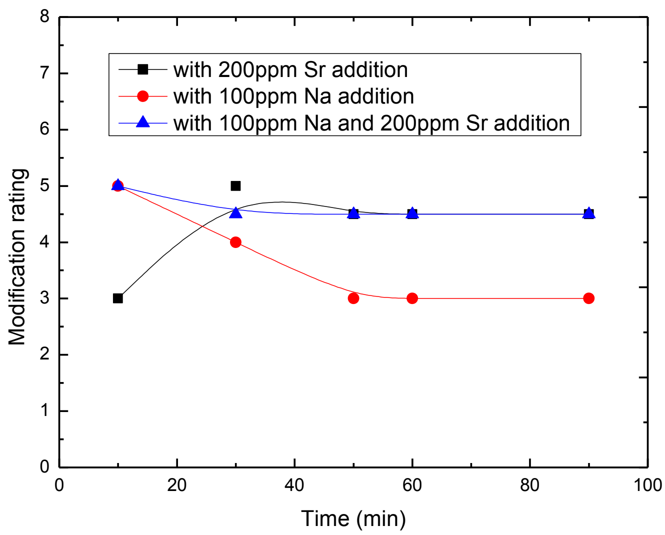

Figure 7. Modification rating a function of holding time of holding time

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3.3.Modification with sodium and strontium combined

Figure 7 shows the modification rating as a function of holding time at 100ppm Na and 200ppm Sr. The results show that it has a good modification over 60min. At 10 min, modification rating of Al-Si is a full modification. A full modification is at 30min when Sr is added alone, It is obvious that there is a shorter incubation for adding Sr and Na compared with Sr. Moreover, it does not show obvious effect of modification fading for combining addition of Na and Sr.

4. Discussion

Na and Sr are commonly used in Al–Si alloys to modify the morphology of eutectic Si and enhance its mechanical properties. Microstructure examinations show that reasonable concentration Sr or Na is sufficient for well-modified of the eutectic silicon. However, Na fades considerably more quickly than expected in general. Na fades due to oxidation reactions with the surrounding environment and modification effect on the eutectic Si is lost. Sr modifier has some weakness, which is a long incubation. with combining addition of Na-Sr, full modification is fairly constant with increase of holding time and without obvious modification fading. It can take effect quickly and decrease the time of incubation. At the same time, no evidence of Sr-Na intermetallics is found in the samples from the bottom of the melt in this study. It is therefore believed that no deleterious reaction is founded between Na and Sr.

L. Lu found that Na addition was likely to promote Sr vaporization and/or oxidation kinetically, leading to a progressive loss of both modifiers[10]. Figure 7 shows that modification rating has been kept constant over 120min. It is concluded that Sr does not cause a large loss during this period. The possible reason for this difference is the atmosphere of modification. This relative quick Sr fading may be related to large surface to volume ratio of the small laboratory furnces. As L. Lu had already discussed, due to its high solubility in liquid Na and limited solubility in molten Al, Sr is expected to migrate upwards from the molten Al into the liquid Na layer. In the open space, Sr is continuously depleted with Vaporization and/or oxidation until its depletion[10]. However, in a relatively closed environment, there is no further loss of Sr from the liquid Na layer. The lifetime of Na-Sr modified Al-Si alloy is different, depending on the initial content of Na-Sr in the melt, melt circumstances, surface to volume ratio of the furnces. For example, the turbulence of melt and bubbling during degassing will make Na-Sr easily to fade.

Based on the above discussion, it can be concluded that the effect of Na is more transient whereas Sr is more persistent. Combining addition of Sr and Na appeares to reduce incubation time compared for Sr alone. It is not deleterious reaction between Na and Sr, but rather that a combination is beneficial in giving prolonged modification (less fading). Consequently, modification with sodium and strontium combined can produce a well-modified microstructure over a long period.

5. Conclusion

1. The appropriate concentration of Sr and Na is sufficient for well-modified of the eutectic silicon.
2. It is not deleterious reaction between Na and Sr, but rather that a combination is beneficial in giving prolonged modification (less fading).
3. Modification with sodium and strontium combined provides a constant long term modificationand in a shorter incubation.

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