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Microstructure and mechanical properties of Al-Fe-V-Si alloy and composites

BolüXiao*, Jianzhong Fan, Lihua Zhou and Likai Shi

National Engineering Research Center for Non-Ferrous Metal Composites, General Research Institute for Nonferrous Metals, Beijing 100088, People's Republic of China

Al-Fe-V-Si alloy and composites from it were prepared by a powder metallurgy (PM) route as well as by mechanical alloying (MA). Globular particles referred to as α-Al_{13} consisted of a quaternary silicide of $Al_x(FeV)_ySi$ and α-AlFeSi diminished after ball milling and grows slightly during the fabrication process. Whereas, the particle in the PM samples grew extensively. For PM samples, the high temperature mechanical strength of the composite is slightly higher than for the unreinforced alloy.

Key words: Al-Fe-V-Si, mechanical alloying, powder metallurgy.

Introduction

Dispersion strengthened aluminum alloys based on the Al-Fe-V-Si system have been developed by means of a rapid solidification process (RSP) in the past decades [1-7]. The Al-Fe-V-Si alloy system exhibits excellent high-temperature mechanical properties due to the ultrafine cubic silicide intermetallic phase, $Al_{12}(Fe,V)_3Si$, and to the low coarsening rate of the spherical precipitate particles [1-7]. Considerable attempts have been made to gain metastable $Al_{12}(Fe,V)_3Si$ particles through melt spinning [8-10]. Meanwhile, gas atomizing with a relative lower cooling rate is also an important method to fabricate the alloy and is a candidate for engineering applications. However, whether by melt spinning or gas atomizing, the particle grows into the stable phase during the subsequent powder metallurgy process leading to a decrease in the high temperature mechanical properties. Therefore, understanding the effect of the processing on the microstructure and mechanical properties is crucial for application of these materials.

In the present study, mechanical alloying as well as powder metallurgy was conducted on gas atomized powder to prepare Al-Fe-V-Si alloy and its composites. Microstructures and mechanical properties were investigated.

Experimental

Materials

The gas atomized Al-7.8Fe-1.3V-1.8Si (wt.%) powders (200 mesh) and SiC particulate with a nominal size of 7 μm were used as raw materials. Stainless steel balls were used for the MA process with a ball to powder ratio of 40:1 by weight. The powder was milled at a rate of 180 rpm for 30h under an argon atmosphere and no process controlling agent was used. SiC particulates with gas atomized alloy powder were mixed to fabricate SiC_p/Al-Fe-V-Si composites and unreinforced alloy. The sample codes are shown in Table 1. Three types of powder were degassed at 460 °C and compacted into billets. The billets were extruded into bars at 410 °C with an extrusion ratio of 25:1.

Table 1. Samples of experimental materials

Preparation method	Al-Fe-V-Si	11 vol.% SiC_p/Al-Fe-V-Si
MA	2	
PM	1	3

Test procedure

The tensile test samples were 20 mm in gauge length and 3 mm in diameter with the axis parallel to extrusion direction. The tensile tests were performed at 25 and 315 °C. Samples for high temperature tests were soaked for 15 minutes. Standard metallographic and transmission electron microscope samples were prepared from powder and bars. X ray diffraction and energy dispersive Xray spectroscopy (EDS) were used to identify the phases in the samples.

Results and Discussion

Microstructure

Experimental powder diffraction patterns of the gas atomized and ball milled powders as well as the bars are shown in Fig. 1. Typical optical micrograph of the samples in shape of powder and bar are shown in Fig. 2.

*Corresponding author:
Tel : +86-10-82241232
Fax: +86-10-62355099
E-mail: xiaobolv@163.com

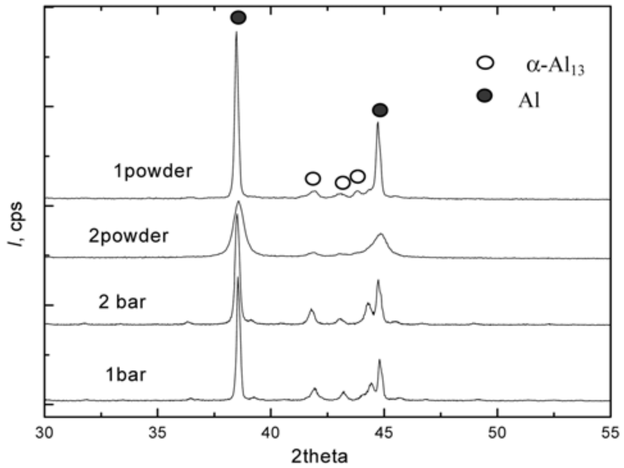

Fig. 1. XRD patterns of Al-Fe-V-Si alloy powder and bulk materials.

The XRD patterns and EDS analysis of the powder sample 1 indicates that quaternary silicides (Fig. 2a) with a formula of $Al_{10.2}(Fe,V)Si_{1.4}$ formed. Some authors suggest a stoichiometry of the quaternary silicide as $Al_{12}(Fe,V)_3Si$ [8-10], or $Al_{13}(Fe,V)_3Si$. It can be inferred that α-AlFeSi also formed together with the quaternary particles constituting the α-Al_{13}. Figure 2b shows that spherical α-Al_{13} particles are distributed along the extrusion direction in the extruded bar of sample 1.

The Al peak was broadened by the formation of the α-Al solid solution after ball milling and the peaks from silicides almost disappeared (Fig. 1). These results agree well with the metallographic observation (Fig. 2c). The spherical particles diminish after ball milling for 30h. However, the phase emerges again after reheating during hot pressing and extrusion (Fig. 1). Figure 2d shows a refined microstructure in sample 2. Figure 3 shows TEM images of as extruded samples 1 and 2. The grains as well as the particles are fine with a uniform dispersion of particles. For sample 1, the particles are coarser and distributed along the grain boundaries. The mechanical alloying gives the benefit of increasing the solid solubility of the secondary element. The α-Al_{13} therefore becomes dissolved in the Al matrix by milling. Moreover, a high-density of dislocations and vacancies as well as subgrain boundaries are formed in the matrix. The particles of silicide precipitated preferentially in these sites during reheating. A uniform distribution of fine particles is therefore produced in the process.

Tensile properties

Table 2 shows the tensile properties of samples 1 and 3 at 25 and 315 °C. The strength of the Al-Fe-V-Si alloy here seemed to be lower than that reported in literature except for the elongation [10], this could be attributed to the higher hot press temperature (460 °C) leading to coarser silicide particles in matrix. The

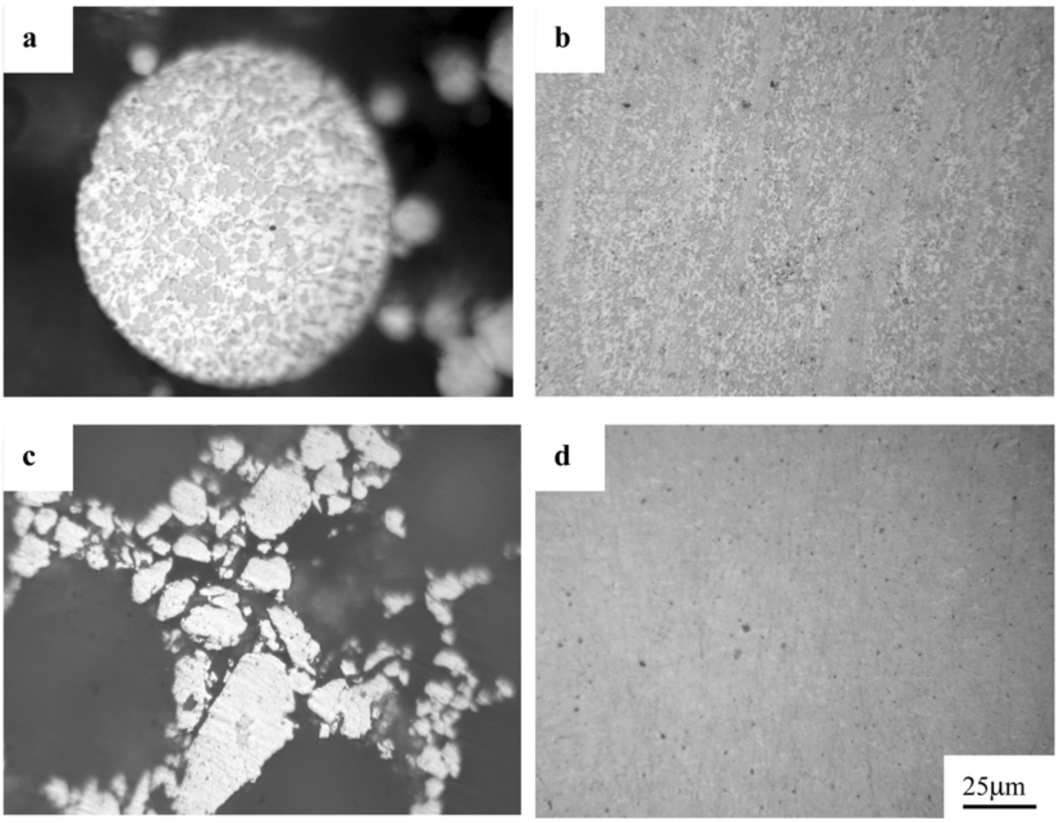

Fig. 2. Optical micrographs of Al-Fe-V-Si alloy and composite. a) powder of sample 1; b) bar of sample 1; c) powder of sample 2; d) bar of sample 2.

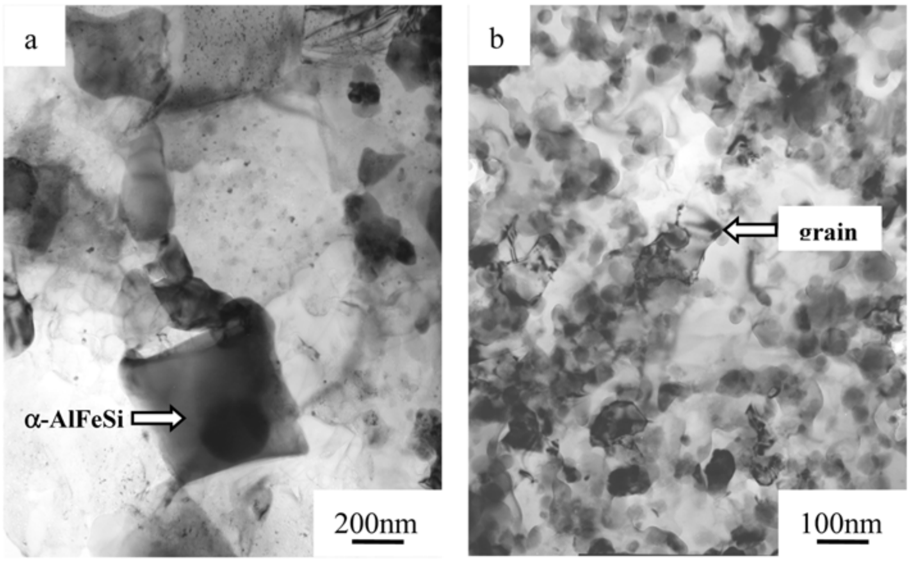

Fig. 3. TEM images of Al-Fe-V-Si alloy a) bar of sample 1; b) bar of sample 2.

Table 2. Tensile properties of Al-Fe-V-Si alloy and composite

Sample	Temperature, °C	UTS, MPa	Yield stress, MPa	Elongation, %
1	25	281	350	15
1	315	149	163	11
3	25	413	442	4.6
3	315	189	199	3.0

addition of SiC particulate has an obvious effect on the yield strength at ambient temperature whereas only a small increasing high temperature strength. Further microstructural investigations should be conducted to understand the effect of SiC particulate on mechanical properties.

Conclusions

1. α-Al_{13} phase particles consisting of $Al_{12}(Fe,V)_3Si$ and α-AlFeSi diminish with the formation of α-Al solid solution after ball milling. The ball milling is of benefit to refine the microstructure and control the distribution of the particles through the fabrication process.

2. The addition of SiC particulate gives a large increase in strength at room temperature but only a small increase in high temperature strength.

References

1. D.J. Skinner, R.L. Bye, D. Raybould, and A.M. Brown, Scripta Metall. 20 (1986) 867-872.
2. R.E. Frank, and J.A. Hawk, Scripta Metall. 23 (1989) 113-115.
3. G.S. Murty, and M.J. Koczak, J. Mater. Sci. 24 (1989) 510-514.
4. M.A. Rodriguez, and D.J. Skinner, J. Mater. Sci. Lett. 9 (1990) 1292-1293.
5. S.C. Kgatri, and M.J. Koczak, Mater. Sci. Eng. A 167 (1993) 11-21.
6. S. Hariprasad, S.M.L. Sastry, K.L. Jerina, and R.J. Lederich, Metall. Trans. 24A (1993) 865-873.
7. S. Mitra, Metall. Trans. 27A (1996) 3913-3923.
8. M. Cooper, and K. Robinson, Acta Cryst. 23 (1967) 1106-1107.
9. K. Sugiyama, N. Kaji, and K. Hiraga, Acta Cryst. C54 (1998) 445-447.
10. S. Hariprasad, S.M. Sastry, and K.L. Jerina, J. Mater. Sci. 31 (1996) 921-925.