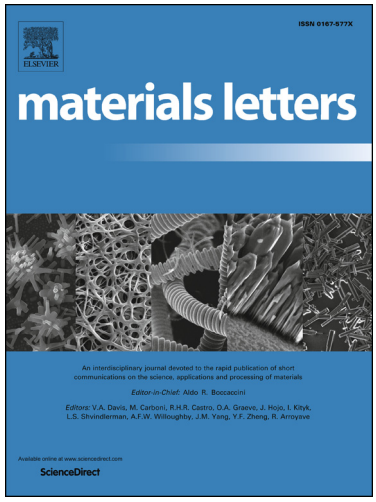

Effect of Pr inoculation and crystal size on the Hall-Petch relationship for Al-30wt%Mg_2Si composites

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Effect of Pr inoculation and crystal size on the Hall-Petch relationship for Al-30wt%Mg_2Si composites

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Abstract: The effect of varying levels of Pr inoculation on the microstructure, granularity, and mechanical properties of an Al-30%Mg_2Si composite was studied. When the Pr content was increased to 0.8wt%, the refinement was ideal. Similarly, the mechanical properties such as Ultimate Tensile Stress (UTS), Breaking Elongation (BE), and Vickers Microhardness (VM) values were improved. The relationship between crystal size and UTS or VM was described using the Hall-Petch relationship.

Key words: composite materials; X-ray techniques; Pr inoculation; nanosize; Hall-Petch

1. Introduction

Particulate reinforced aluminium metal matrix composites (MMCs) have attracted great attention recently because of their low density, high wear resistance, low thermal-expansion, and much lower costs of production [1-3]. Al–Mg_2Si composites have potential application for use in automobile brake discs because intermetallic Mg_2Si exhibits a high-melting point, low density, high hardness, low thermal expansion coefficient and high elastic modulus [4]. However, Mg_2Si is very brittle which complicates its processing and limits its further application, especially at low temperatures [5]. Moreover, the primary Mg_2Si particles exhibit coarse morphology and brittleness in the composites, which has a detrimental effect on the overall mechanical properties [6,7]. Thus, the primary Mg_2Si particles in aluminium MMCs must be modified to change their morphology and distribution to improve the overall mechanical properties.

The equilibrium diagram of Al-Mg_2Si is pseudo-eutectic [8,9], and the pseudo-binary phase diagram of Al-Mg_2Si was confirmed by Li et al. and Zhang et al. [10,11]. Since then, different Mg_2Si contents in Al-Mg_2Si composites were studied in range of 0wt%Mg_2Si to 25wt%Mg_2Si. However, higher concentrations of Mg_2Si in aluminium MMCs have rarely been reported, as the Al-30wt%Mg_2Si composite features primary Mg_2Si particles that dominate the microstructural and mechanical properties. Thus, investigations into the modification of the Al-Mg_2Si composites are needed. Rare earth (RE) metals, such as Y [12], Ce [13], Nd [14], and La [15] can effectively refine the microstructure and enhance the strength and ductility of Al–Mg_2Si. However, the effect of Pr on the crystal size of the Mg_2Si phase and the relationship between the crystal size and mechanical properties have not been explored.

In this study, excess Mg_2Si-reinforced aluminium MMCs, i.e. the Al–30wt%Mg_2Si composites, were investigated. Pr was used to modify the Mg_2Si particles to investigate the effect of Pr on microstructure, granularity, and mechanical properties of Al–30wt%Mg_2Si prepared by an *in-situ* process. Furthermore, the relationship between the crystal size of Mg_2Si and the mechanical properties is investigated.

2. Experimental procedures

The Al–30wt%Mg_2Si composite was synthesized with aluminium (ingot, 99.70% purity), magnesium (ingot, 99.61% purity), and silicon (block, 99.22% purity) by an *in-situ* process. Pr inoculation was performed by direct addition to the melts, wherein the Pr mass fraction ranged from 0.2wt% to 0.8wt% in steps of 0.2wt%. Melts with and without Pr were cast into a permanent steel mould, and a composite ingot was obtained. Further details of the production process can be found elsewhere [15].

Metallographic specimens were sectioned from the same positions. The surface morphology and distribution of the composite were observed by SEM. Phase composition and crystal size were detemined using XRD. Ultimate tensile