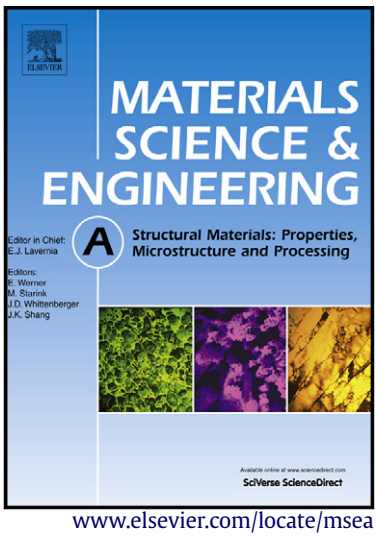

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Multi-component solid solution and cluster hardening of Al-Mn-Si alloys

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Abstract: Tensile tests on Al-Mn-Si ternary alloys show that a small amount of Si increases significantly the strength compared to Al-Mn binary alloys with the same concentration of Mn. This cannot be explained by classical theories for multi-element substitutional solid solution hardening under the assumption of no interaction between different alloying elements. A new simplified cluster strengthening model which addresses both the chemical and size misfit effects of atom dimers is proposed this work. The binding energies and misfit of dimers were estimated by first principles atomistic simulations. The prediction results of the model are reasonably consistent with the experimental results. It shows that the main strengthening contribution is due to the misfit of dimers.

Keywords: aluminium alloys; cluster; strengthening mechanism; modelling

1. Introduction

The interaction between solute atoms and dislocations is an important strengthening mechanism for alloys. Solid solution hardening in binary alloys has been extensively studied and its principle has been well understood [1, 2]. However, multi-element solution hardening, which is essential for commercial alloys, has been paid much less attention. The solute strengthening contribution from solute atoms of type i in binary alloys is denoted $\Delta\tau_i$. Under the assumption that there is no interaction between solute atoms [3], the superposition of multi-element solution hardening is

$$\Delta\tau^p = \sum\nolimits_i \Delta\tau_i^{\,p} \tag{1}$$

Here $1 \le p \le 2$. Equation (1) is a general superposition law at finite temperatures and in the athermal limit [4]. The value $p=1$ is justified when a high density of weak obstacles (e.g. solute atoms) are mixed with strong ones such as forest dislocations and non-shearable precipitates [5]. The choice $p=2$ is suitable for obstacles of similar strengths [5]. In literatures $p=1.5$ is often used for solute strengthening [6-8], which can be obtained from Labusch theory