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Effect of re-melting on particle distribution and interface formation in SiC reinforced 2124Al matrix composite

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ABSTRACT

The interface between metal matrix and ceramic reinforcement particles plays an important role in improving properties of the metal matrix composites. Hence, it is important to find out the interface structure of composite after re-melting. In the present investigation, the 2124Al matrix with 10 wt.% SiC particle reinforced composite was re-melted at 800 °C and 900 °C for 10 min followed by pouring into a permanent mould. The microstructures reveal that the SiC particles are distributed throughout the Al-matrix. The volume fraction of SiC particles varies from top to bottom of the composite plate and the difference increases with the decrease of re-melting temperature. The interfacial structure of re-melted 2124Al–10 wt.%SiC composite was investigated using scanning electron microscopy, an electron probe micro-analyzer, a scanning transmission electron detector fitted with scanning electron microscopy and an X-ray energy dispersive spectrometer. It is found that a thick layer of reaction product is formed at the interface of composite after re-melting. The experimental results show that the reaction products at the interface are associated with high concentration of Cu, Mg, Si and C. At re-melting temperature, liquid Al reacts with SiC to form Al_4C_3 and Al–Si eutectic phase or elemental Si at the interface. High concentration of Si at the interface indicates that SiC is dissociated during re-melting. The X-ray energy dispersive spectrometer analyses confirm that Mg- and Cu-enrich phases are formed at the interface region. The Mg is segregated at the interface region and formed $MgAl_2O_4$ in the presence of oxygen. The several elements identified at the interface region indicate that different types of interfaces are formed in between Al matrix and SiC particles. The Al–Si eutectic phase is formed around SiC particles during re-melting which restricts the SiC dissolution.

1. Introduction

Ceramic-particle reinforced metal-matrix composites (MMCs) have become known as an important class of material for their excellent properties such as high specific modulus, high temperature strength, good wear resistance and low coefficient of thermal expansion as compare to its monolithic alloys [1,2]. Optimum interface bonding in composite must be required to

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obtain the best combination of properties. Recently, there has also been a growing interest in recycling of metal matrix composites due to environmental factors that influence the physical and mechanical properties of composites [3,4]. Schuster et al. [3] successfully recycled the MMCs scrap to prepare chill cast ingot with similar fluxing and degassing technique used for casting composites without scrap.

The composite materials are sensitive to the type of reinforcements, mode of fabrication process and detailed re-melting recycling parameters such as temperature, holding time and number of times of recycling. The MMCs fabricated by liquid metallurgy route (LMR) are most cost-effective in comparison with MMCs produced by solid state processing [5,6]. But all the theoretical and technological difficulties in LMR are not solved entirely which restricted the applications of these materials. For instance, when the material is fabricated by LMR especially during the recycling a gradient of chemical potential exists at the interface of particles and matrix which provides a driving force for chemical reaction. The interface reaction during fabrication or re-melting–recycling depends on processing parameters, especially temperature and chemical composition of both matrix and reinforcement particles. It is difficult to achieve desired bonding between SiC reinforced particles and aluminium matrix because the wettability of ceramic particles in aluminium matrix is poor. In case of Al–SiC composite, Al reacts with SiC particle to form Al_4C_3 and Si. This reaction is accompanied by a rejection of Si in the melt. Janghorban [7] proposed that the carbide is water soluble and Legoux et al. [8] reported that carbide has detrimental effects on the properties of the composite. The formation of Al_4C_3 during fabrication or recycling of Al–SiC composites is a major concern. Many investigations have been carried out on the stability of SiC in aluminium matrix composite. The interfacial reactions between metallic matrix and ceramic reinforcement have been studied [9–11]. The chemical reaction between SiC and Al matrix increased with increasing re-melting temperature and the number of recycling run [10,11]. Lee et al. [12] studied the interfacial reaction above liquidus temperature in Al–SiC composite. Fan et al. [13] reported that the chemical reaction of Al–SiC composite during re-melting could be prevented by controlling the melting temperature, by adding a given amount of silicon to the Al melt. Most of these research works were carried out at an ambient temperature. The effect of interfacial reaction of re-melting composite has been ignored. There is a little information available on the chemical reactions during re-melting of Al–SiC composites above the liquidus temperature, even though this is quite necessary to understand the recycling mechanism.

In the present investigation, the effect of re-melting recycling of 2124Al–10 wt.%SiC composites at different re-melting temperatures on the distribution of SiC particle throughout the matrix as well as elemental distribution at the interface have been reported. The morphology and distribution of the reaction products are also examined.

Table 1 – Chemical composition of 2124 Al Alloy (wt.%).

Alloy	Si	Mg	Cu	Fe	Mn	Cr	Zn	Al
2124Al	0.8	1.5	4.4	0.3	0.8	0.10	0.25	Bal

2. Experimental

The chemical composition of the 2124Al alloy is given in Table 1. SiC particles used in this study are α-SiC having an average particle size of 80–120 μm. 2124Al alloy matrix 10 wt.%SiC particle reinforced composites were prepared by stir casting route and cast into a cast iron mould in the form of slab. The cast slabs were hot forged followed by hot rolling up to 60% deformation after soaking at 430 °C for 1 h.

The re-melting of 2124Al–10 wt.%SiC particle reinforced composite was carried out at 800 and 900 °C in a heat resistance furnace for 10 min and poured into a cast iron mould. The temperature variation during each re-melting treatment was ±5 °C. The microstructure of re-melted composite samples was observed under an optical microscope. The particle sizes and volume fraction were measured with using image analysis software. The particle–matrix interface was studied using secondary electron imaging modes by scanning electron microscopy (SEM: JEOL JSM 7000) and a back scattered electron (BSE) imaging mode by an electron probe microanalyzer (EPMA: JEOL JSM 8600). The characterization of the interfacial reaction product with bright field imaging was done with a scanning transmission electron detector (STEM) fitted with scanning electron microscopy. The chemical compositions of the different phases/reaction products were investigated through spot analysis using an X-ray energy dispersive spectrometer (EDX) as a detector attached with the SEM and quantitative elemental analysis was carried out using a wavelength dispersive spectrometer (WDS) as a detector attached with the EPMA. For STEM image observation, discs of diameter

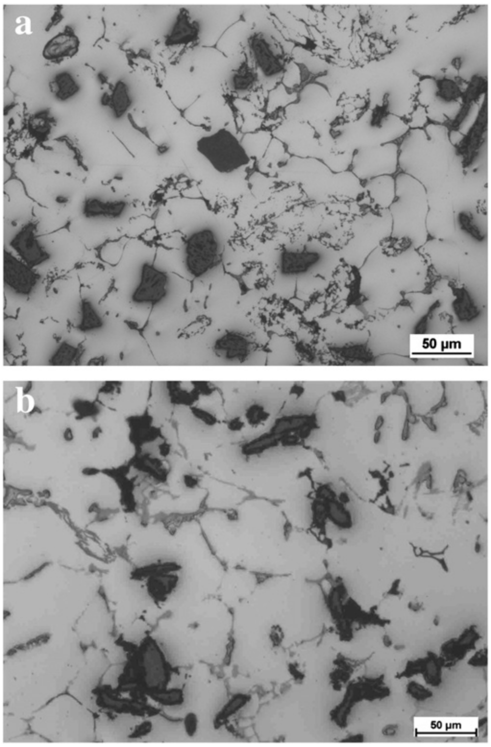

Fig. 1 – Optimal microstructure of 2124Al–10SiC composites (a) as-cast, (b) re-melted.