Chapter 1
Processing Routes, Mechanical, and Tribological Properties of Light Metal Matrix Nanocomposites

S. Jayalakshmi
Bannari Amman Institute of Technology, India

R. Arvind Singh
Bannari Amman Institute of Technology, India

ABSTRACT

The chapter highlights the various processing/synthesizing routes of Light Metal Matrix Nanocomposites (LMMNCs), their microstructural characteristics, mechanical behaviour, and tribological properties. LMMNCs are advanced materials, in which nano-sized ceramic particles are reinforced into Al/Mg matrices. In conventional Metal Matrix Composites (MMCs), the incorporation of micron sized reinforcements in the matrix usually results in a considerable improvement in hardness and ultimate strength when compared to the unreinforced base material. However, most of these composites do not show plastic deformation (little or no yield) and exhibit drastic reduction in ductility. This poses a major limitation for MMCs to be used in real-time applications. In order to overcome this drawback, Al/Mg composites with nano-scale reinforcements have been developed. Based on numerous research works, it has been established that LMMNCs are better materials that possess superior properties, wherein both strength and ductility improvements along with excellent wear resistance can be achieved.

1. INTRODUCTION

Metal matrix composites (MMCs) are advanced materials in which strong and stiff ceramic constituents are reinforced into metallic matrices. The matrix is the continuous phase and the reinforcing phase (micron sized) is usually in the form of fibres (continuous or short)/whiskers/particles (Chawla & Chawla, 2006; Clyne & Withers, 1995). Examples of metal matrices include Al, Ti, Mg,

DOI: 10.4018/978-1-4666-7530-8.ch001

Cu and Zn. Light metals/alloys such as Al and Mg are widely preferred for a variety of applications involving aerospace/space, automobile, sports and consumer electronics due to their light weight, ease of processing and flexibility to obtain a wide range of properties (Avedesian & Baker, 1999; Brook, 1998; Friedrich & Mordike, 2006; Polmear, 1995). However, Al and Mg metals/alloys lack thermal stability and their mechanical performance deteriorates at higher operating temperatures, thereby as such they do not satisfy the key materials requirements necessary for real time applications.

Reinforcing hard/strong and thermally stable phases (e.g. SiC, Al_2O_3, B_4C) to a metallic phase (i.e. matrix) in order to make MMCs has been explored in the past. Such MMCs have provided improvement in properties when compared to their base metals/alloys. Amongst various MMCs, those based on light metals such as Al and Mg are highly attractive owing to their light weight and performance capability in terms of specific strength, hardness, stiffness, high temperature mechanical properties and excellent wear resistance (Chawla & Chawla, 2006; Clyne & Withers, 1995; Deuis, Subramanian, & Yellup, 1997; Kainer, 2006; Miracle, 2005; Subra Suresh, Mortensen, & Needleman, 1993; Surappa, 2003; Vaidya & Chawla, 1994). As an example, SiC particle reinforced Al composite has the stiffness similar to that of cast iron (~170 GPa), while having the density close to that of Al (high specific stiffness). Another example is that of a continuous carbon fiber reinforced Al MMC that has the strength and stiffness similar to that of high strength steel, but with density close to that of Al (http://www.alsic.com/metAlmatrix-composite-mmc.html). Materials with such attractive properties have applications ranging from electronic industries to military (Rohatgi, 1996). However, in spite of these advantages, there has remained a major drawback that restricts wider use of these materials, namely their poor ductility. The poor ductility (little or no yield/ plastic deformation) arises due to: (i) the presence of hard but brittle ceramic reinforcement phases and (ii) the micron size of the reinforcements that causes undesired agglomeration/cluster-formation during their processing. In this context, incorporation of nano sized reinforcements to create light metal matrix nanocomposites (LMMNCs) is a promising alternative, which can provide superior mechanical properties with better ductility (Choi, S.-M.& Awaji, 2005; Gupta & Sharon, 2011; Suryanarayana & Al Aqeeli, 2013). Nano particles when uniformly distributed give rise to significant enhancement in mechanical and tribological properties due to the 'dispersion strengthening-like' effect, which can impart higher strength along with ductility retention/enhancement. It should also be noted that processing methods used to produce micron sized reinforced composites (MMCs) can also be easily adopted to synthesize LMMNCs, making them flexible in terms of their processing. Moreover, enhancement in properties can be achieved even at lower volume fractions of nano reinforcements (<2%), whereas with micron scale reinforcements, higher volume fractions are required (>>10%) (Gupta & Sharon, 2011; Suryanarayana & Al Aqeeli, 2013).

2. BACKGROUND

Global concern over energy crisis that is being faced world-wide has seriously propelled research towards identifying robust solutions to meet the need. Rapid depletion of oil reserves, increasing demand for fuel efficiency and regulations on emission has turned the attention towards light weight materials. Research on these materials is in focus to achieve multiple performance reliability, along with easier material processing, machinability/formability and high load bearing capacity/structural strength. Energy efficiency, recyclability and sustainability are also in the focus. In this context, R&D of Al and Mg is of great interest, especially for weight critical applications such as in automotive, aviation, sports,