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Development of Hierarchical Magnesium Composites Using Hybrid Microwave Sintering

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ABSTRACT

In this work, hierarchical magnesium based composites with a micro-architecture comprising reinforcing constituent that is a composite in itself were fabricated using powder metallurgy route including microwave assisted rapid sintering technique and hot extrusion. Different level-I composite particles comprises sub-micron pure aluminum (Al) matrix containing Al_2O_3 particles of different length scale (from micrometer to nanometer size). Microstructural characterization of the hierarchical composites revealed reasonably uniform distribution of level-I composite particles and significant grain refinement compared to monolithic Mg. Hierarchical composite configurations exhibited different mechanical performance as a function of Al_2O_3 length scale. Among the different hierarchical formulations synthesized, the hierarchical configuration with level-I composition comprising Al and nano-Al_2O_3 (0.05 μm) exhibited the highest improvement in tensile yield strength (0.2% YS), ultimate tensile strength (UTS), tensile failure strain (FS), compressive yield strength (0.2% CYS) and ultimate compressive strength (UCS) (+96%, +80%, +42%, +80%, and +83%) as compared to monolithic Mg. An attempt has been made in the present study to correlate the effect of different length scales of Al_2O_3 particulates on the microstructural and mechanical response of magnesium.

KEYWORDS: Hierarchical magnesium composite; microwave sintering; powder metallurgy; ball milling; Al and Al_2O_3 reinforcements; mechanical properties.

INTRODUCTION

Powder metallurgy (PM) is one of the most common approaches for the synthesis of high performance components for various applications [Schaffer et al., 1999; German, 1984], and can be used for both metals and metal based composites [German, 1984; Lloyd, 1994]. In the powder metallurgy processing route, sintering is considered the most essential step to achieve atomic diffusion induced mechanical integrity and minimal porosity in the structure of the processed materials [Callister, 2007]. Effectiveness of the sintering procedure is critically dependent on the temperature, time, heating rate and environments. Sintering can be done by traditional methods of heating such as resistance heating [Schaffer et al., 1999; German, 1984] or by the more recently introduced method of using microwaves [Rödiger et al.,1998; Leparoux et al., 2003; Breval et al., 2005]. In a typical resistance heating furnace, the direction of heating is from outside to inside of the powder compact, while for microwaves the direction