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Optimization of cellular structure of aluminum foams produced by powder metallurgy method

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ABSTRACT

This paper describes a new method for optimizing the cellular structure of AlMg4Si8 alloy foams manufactured via powder metallurgy. The cellular structure was improved by pretreating TiH_2 with a layer of Sn powder, which was then remixed with an AlMg4Si8 alloy used as the raw material for the preparation of the precursor. TiH_2 was completely encapsulated in the molten Sn at an early stage of foaming when the matrix alloy was still solid, so that liberated H_2 was fully captured when TiH_2 began to decompose. The interpore flow of H_2 along the cracks in the solid matrix was avoided, improving the utilization ratio of TiH_2 as a blowing agent. After determining that 4.0 wt% Sn cladding was capable of almost completely encapsulating 0.5 wt% TiH_2, the final cellular structure was optimized and regular circular pores were obtained.

1. Introduction

The use of powder metallurgy (PM) for manufacturing aluminum foams has developed rapidly as it is particularly suitable for making net-shaped foams, and more generally, has further advanced casting and PM technologies. The theory of foaming processes and mechanisms have been gradually perfected over many years of research, with studies showing that the quality of the cellular structure produced is affected by the pore formation, growth, stabilization, and coalescence during foaming, while final pore structure is determined by the interplay of these complicated processes [1]. Additionally, foam stability has been studied, resulting in the development of several techniques, such as the addition of SiC particles.

Simulation and experimental results have shown that aluminum foams formed with an excellent cellular structure have excellent mechanical properties [2], such as foams wherein pores are shaped like a circle. The appearance of superior cellular structures is determined by the appropriate match of the decomposition temperature of TiH_2 and melting temperature of the parent material [3], which illustrates that the blowing agent had not yet decomposed before the metal matrix melted. To date, only two strategies have been used to attain temperature matching. One method uses a pretreatment of TiH_2 to delay decomposition, wherein an initial heat treatment of TiH_2 leads to pre-oxidation and a subsequent application of compounds such as Ni, Al_2O_3, or SiO_2 to coat the TiH_2 surface [4,5]. Another method reduces the melting point of the metal matrix, by using alloys such as AlSiMg or AlSiCu that have lower melting points or larger two-phase regions [6]. These strategies have been used to obtain the best cellular structure possible, but exact temperature matching has not been achieved, and irregular pores often appeared, resulting in an especially unreliable production of good cellular structures.

To improve the pore structure irregularity and provide good reproducibility, a new method for optimizing the cellular structure of aluminum foams manufactured using PM has been recently proposed. Sn was used as an alloying element to dope a parent material, benefiting the liquid sintering of aluminum alloy and structurally stabilizing the foam [7,8]. Sn has a low melting point and is immiscible with Al, but studies on the cellular structure of aluminum foams using a new pretreatment technique where TiH_2 is covered with a layer of Sn powder has not been reported. Therefore, a method of coating TiH_2 with Sn is proposed here improve foam cellular structure.

2. Material and methods

A foamable precursor composed of the alloy AlMg4Si8-(0,4%)Sn and 0.5 wt% TiH_2 was obtained via PM hot-rolling, with powder

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wrapped by metal panels before rolling. The TiH_2 used in this study was heated at 500 °C for 2 h in air. Al, AlMg50, and Si powders with an average particulate size of 75 μm were mixed in fractions leading to an AlMg4Si8 alloy. TiH_2 was encapsulated in Sn using remixing, with the specific process shown in Fig. 1. Air-atomized Sn powders with an average size of 25 μm and 99.7% purity were first mixed with TiH_2 powders (48 μm) in a three-dimensional mixer for 2 h, and then the mixed powder was briquetted, crushed, and sieved to obtain Sn-TiH_2 powders with sizes from 75 to 150 μm. Finally, the Sn-TiH_2 powders were mixed with AlMg4Si8 (75 μm) also in a three-dimensional mixer for 2 h to form the raw materials for a foamable precursor.

A foamable aluminum precursor was produced by hot rolling, and after a stainless steel mold was pre-heated at 720 °C in a resistance furnace, foaming was performed by placing the precursor in the mold for various durations. Then, the final cellular structure

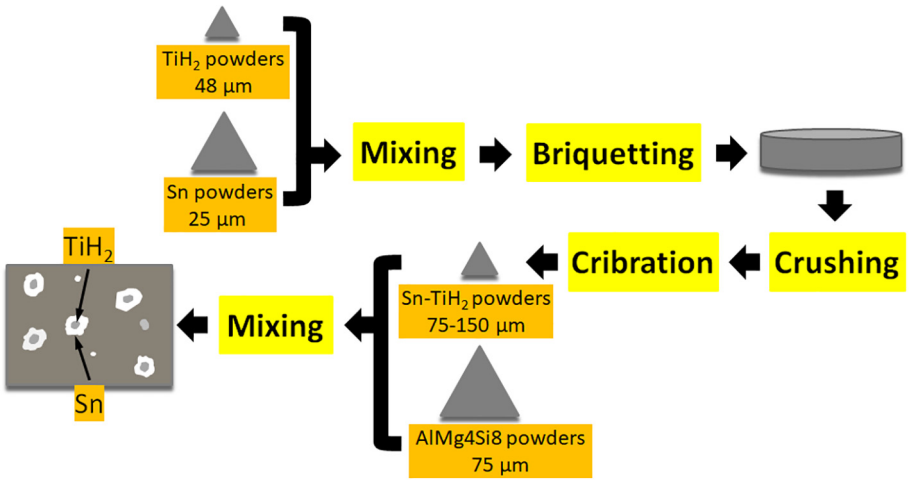

Fig. 1. The flow chart of Sn coating on TiH_2 surface.

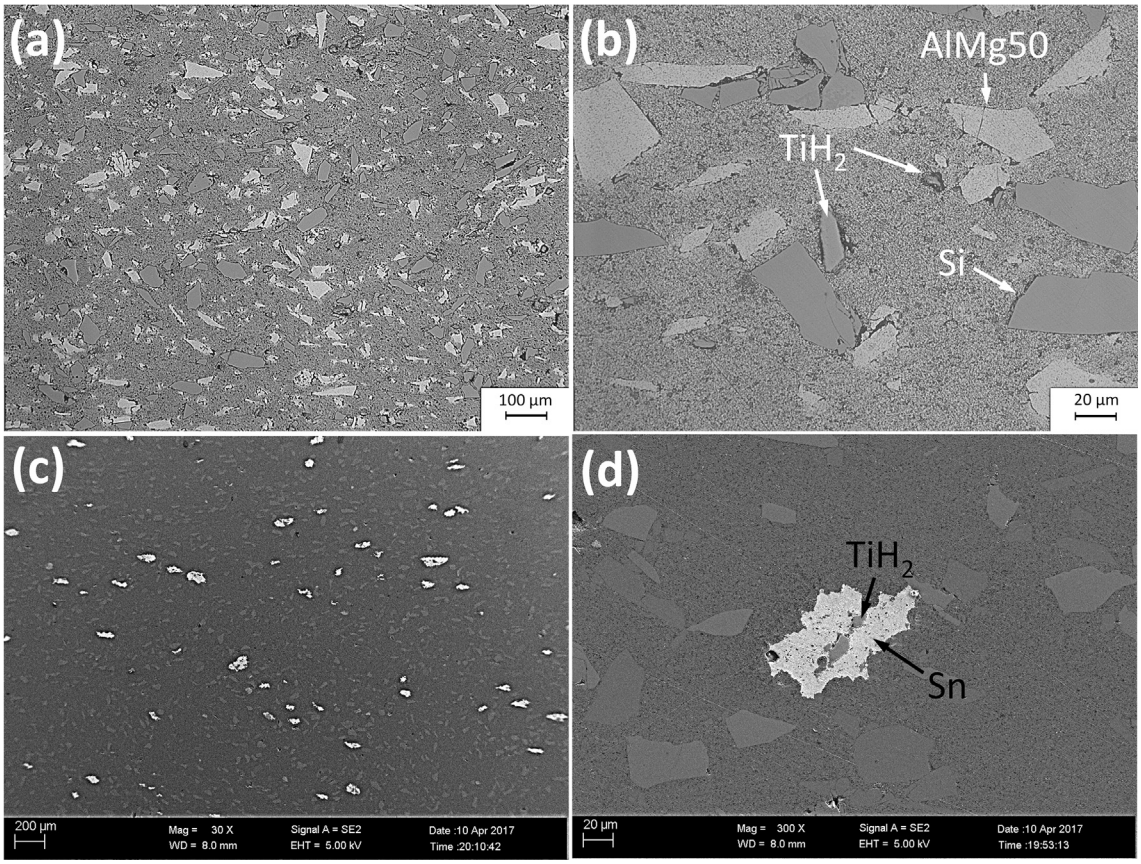

Fig. 2. Microstructures of (a) AlMg4Si8 and (c) AlMg4Si8/Sn4 foamable precursors before the foaming. (b) Magnification image in (a); (d) magnification image in (c).