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Effect of wrapped Zn plate on the densification of Al-MWCNTs composites produced by cold pressing and liquid phase sintering

M.R. Joo [a], H.J. Choi [b], S.E. Shin [a], D.H. Bae [a,*]

[a] Department of Materials Science and Engineering, Yonsei University, Seoul 120-749, Republic of Korea
[b] School of Advanced Materials Engineering, Kookmin University, Seoul 136-702, Republic of Korea

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ABSTRACT

To produce highly dense and cost-effective Al-multi-walled carbon nanotube (Al-MWCNT) composites, the composite powders are wrapped by a Zn plate and then cold-pressed. The green compacts are then sintered at 550 °C, which shows ~99%density after sintering for 24 h. During sintering, Zn atoms fill the voids at the powder boundaries by capillary action and are then dissolved into the Al matrix because of the high solubility of Zn in Al, thus assisting densification of the composite powder. The Al/Zn-based composites containing 4 vol% MWCNTs show compressive yield strength (~380 MPa) and high work hardening capacity.

1. Introduction

Extensive research has been carried out in automobile and aerospace industries to obtain materials with high stiffness and strength, low density, and better formability. In particular, multi-wall carbon nanotubes (MWCNTs), which are carbon-based materials, have been investigated as attractive reinforcing agents for light-metal matrix composites because of their superior mechanical properties such as high stiffness and strength (~1 TPa and ~30 GPa, respectively) as well as low density [1–3].

Metal-MWCNTs composites are usually fabricated by various methods such as powder metallurgy (P/M), melting and solidification, thermal spraying, electrochemical deposition, and molecular level mixing [4]. Among these processes, P/M methods are known to provide homogeneous dispersion, and the high interfacial strength of MWCNTs in the matrix imparts MWCNTs with excellent mechanical properties [4–10]. However, aluminum powder, which inherently possesses natural aluminum oxide on its surface, is very difficult to be consolidated or sintered via conventional processes. Although several consolidation routes such as hot extrusion, hot rolling, spark plasma sintering, friction stir processing, severe plastic deformation, and hot pressing [11] have been suggested, they are costly and cannot meet the economical requirement of industries.

With this scope, several researchers have attempted to produce Al-MWCNT composites using a press-and-sinter process [12]. To compensate for the poor density of the composite, however, a secondary working process (e.g., repressing, hot extrusion, or rolling) is adopted, and this contributes to increased processing cost [7,13,14]. Most importantly, the initial compressing process is conducted at high temperatures [15], which is unsuitable for commercialization in industries.

In this study, we developed Al-based composites containing MWCNTs; addition of Zn enabled the production of high-density composites by a facile cold pressing and sintering route without any additional working processes. We examined the effect of Zn and MWCNTs on the consolidation and sintering behaviors of monolithic Al and Al-based composite powders. Finally, we discuss the contribution of grain refinement, solid solution, and MWCNT dispersion to the strength of the final composite by comparing the experimental measurement and theoretical expectations.

2. Experiment

2.1. Sample preparation

The Al-MWCNT/Zn composite was prepared via a three-step-process that consists of mechanical milling, cold-pressing, and sintering. Al powder (~150 μm diameter, 99.5% purity) and 4 vol% MWCNTs (~20 nm diameter, ~5 μm length, supplied by Applied Carbon Nano Co., Ltd., Korea) were mechanically milled with stainless steel balls (~5 mm in diameter) using an attrition mill at

* Corresponding author.
E-mail address: donghyun@yonsei.ac.kr (D.H. Bae).

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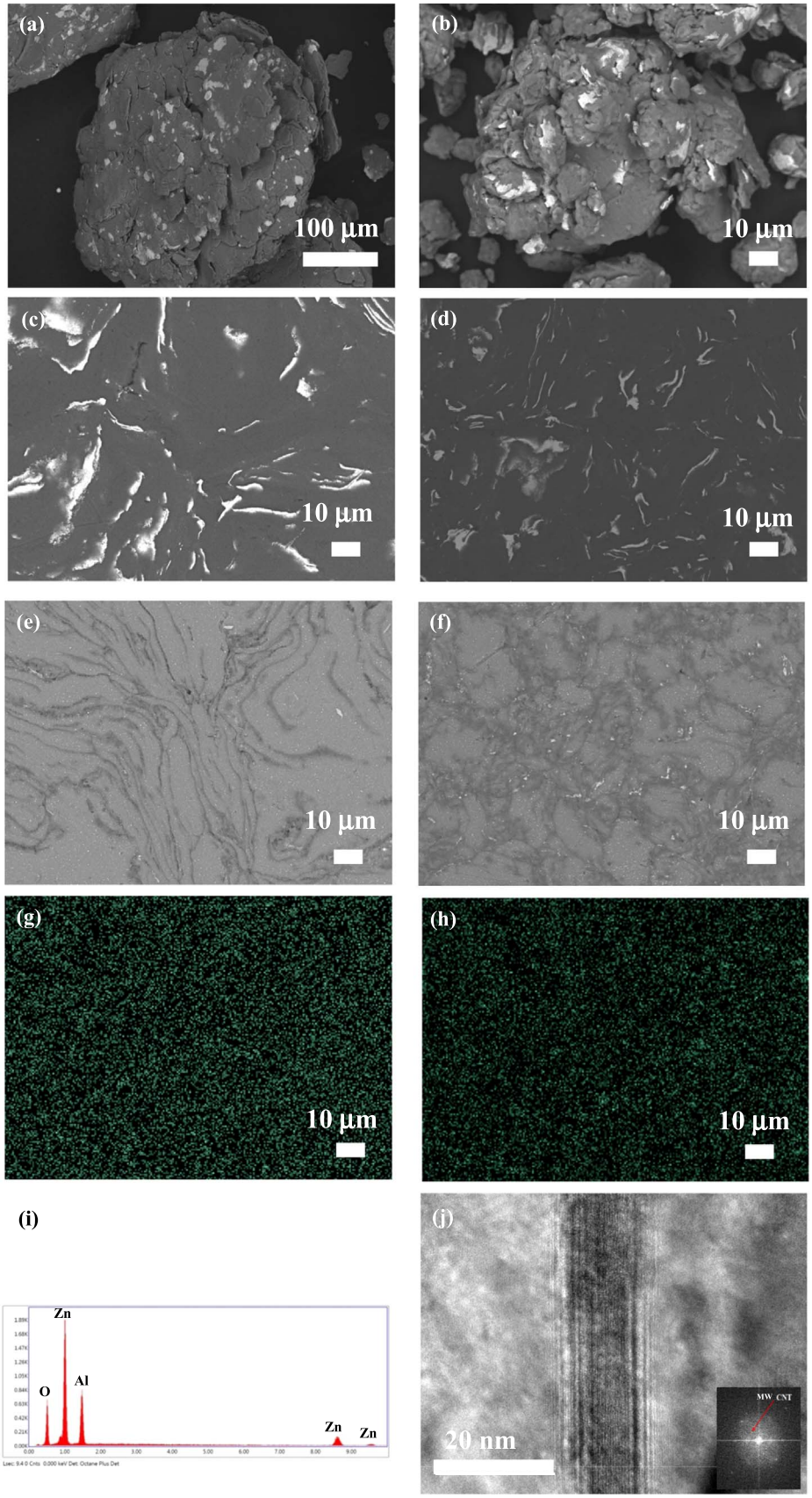

Fig. 1. (a), (c), and (e) SEM images of Al/Zn, and (b), (d), and (f) Al-MWCNT/Zn. Images in (a) and (b) show the ball-milled powder in each composite, images in (c) and (d) are green compact, and images in (e) and (f) are sintered at 550 °C for 24 h. (g) and (h) EDS analysis of Zn in Al/Zn and Al-MWCNT/Zn, respectively, after 24 h of sintering. (i) EDS point analysis of white spots of (f) and (j) TEM image of Al-MWCNT/Zn composites (inset : FFT patterns) (2-column).